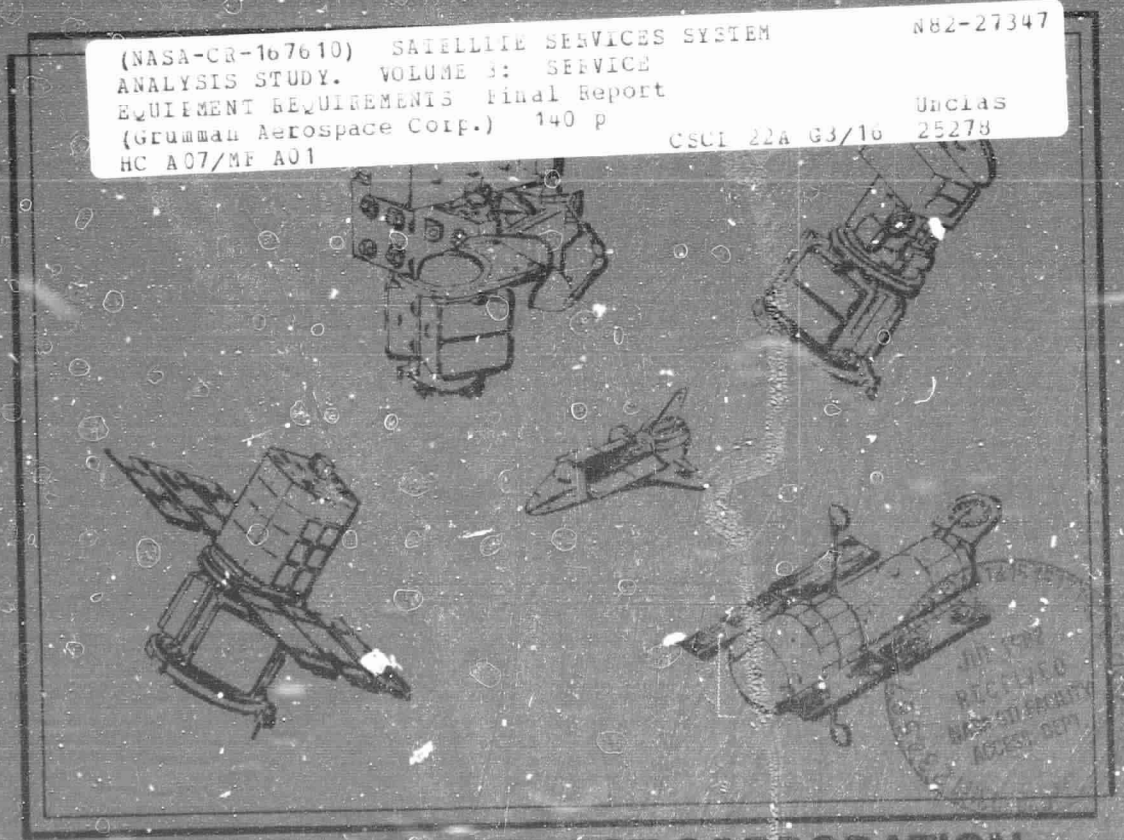
# SATELLITE SERVICES SYSTEM ANALYSIS STUDY

## volume 3 — service equipment requirements





GRUMMAN AEROSPACE CORPORATION

# SATELLITE SERVICES SYSTEM ANALYSIS STUDY

volume 3 — service equipment requirements

prepared for
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

by
Grumman Aerospace Corporation
Bethpage, N.Y. 11714

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# FOREWORD

This study was conducted for the Lyndon B. Johnson Space Center and directed by Contracting Officer's Representatives (COR), Mssrs. Reuben Taylor and Gordon Rysavy. Grumman Aerospace Corporation's study manager was Mr. John Mockovciak Jr.

This final report is presented in seven volumes:

Volume 1 - Executive Summary

Volume 2 - Satellite and Services User Model

Volume 2A - Satellites and Services User Model - Appendix

Volume 3 - Service Equipment Requirements

Volume 3A - Service Equipment Requirements - Appendix

Volume 4 - Service Equipment Concepts

Volume 5 - Programmatics

Volume 3 contains the requirements for on-orbit satellite service equipment associated with Orbiter service operations. Appendices A and B contain functional analyses and on-orbit service mission scenarios that were used to identify requirements and the equipment needed for satellite services. The equipment requirements contained herein also identify the related spacecraft and crew interface requirements.

## ACRONYMS

Abbreviations and acronyms used frequently throughout the Satellite Services System Analysis Study (SSSAS) are defined as follows:

ACS - Attitude Control System

AFD - Aft Flight Deck

ASM - All Sky Monitor

AXAF - Advanced X-Ray Astrophysics Facility

CCTV - Closed Circuit Television

C & DH - Command & Data Handling

C & DL - Command & Data Link

C/O = Checkout

DDT&E - Design, Development, Test & Evaluation

DoD - Department of Defense

DOF - Degrees of Freedom

EMU - Extra-Vehicular Mobility Unit

EVA - Extra Vehicular Activity

FSS - Flight Support System

GAC - Grumman Aerospace Corporation

GEO - Geosynchronous Earth Orbit

GRAVSAT - Earth Gravity Field Survey Mission

GRO - Gamma Ray Observatory

GSE - Ground Support Equipment

HEAO - High Energy Astronomy Observatory

HPA - Handling & Positioning Aid

IR - Infrared

IRAD - Independent Research and Development

IUS - Inertial Upper Stage

IVA - Internal Vehicular Activity

JSC - Johnson Space Center

KSC - Kennedy Space Center

LAPC - Large Area Proportional Counter

LASS - Large Amplitude Space Simulator

LASSII - Low Altitude Satellite Studies of Ionospheric Irregularities

LEO - Low Earth Orbit

LOS - Line-Of-Sight

MDF - Manipulator Development Facility

MFR - Manipulator Foot Restraint

MMS - Multimission Modular Spacecraft

MMU - Manned Maneuvering Unit

MRV - Manned Reconnaissance Vehicle

MTV - Maneuverable Television

NOSS - National Oceanic Satellite System

OAO - Orbiting Astronomical Observatory

OBC - Onboard Checkout

OCC - Operations Control Center

OCP - Open Cherry Picker

OMS - Orbital Maneuvering System

PAM A - Payload Assist Module (type) A

PAM D - Payload Assist Module (type) D

PIDA - Payload Installation & Deployment Aid

PM I/II - MMS Propulsion Module I & II

POCC - Payload Operations Control Center

POM - Proximity Operations Module

RCS - Reaction Control System

RMS - Remote Manipulating System

ROM - Rough Order of Magnitude

S/C - Spacecraft

SE&I - System Engineering & Integration

SMM - Solar Maximum Mission

SRM - Solid Rocket Motor

SSS - Satellite Services System

SSSAS - Satellite Services System Analysis Study

S/S - Subsystem

S/SUM - Satellite and Services User Model

STE - Special Test Equipment

STS - Space Transportation System,

TDRS(S) - Tracking & Data Relay Satellite (System)

TMS - Teleoperator Maneuvering System

TV - Television

UARS - Upper Atmospheric Research Satellite

UV - Ultraviolet

VSS - Versatile Service Stage

WBS - Work Breakdown Structure

WETF - Weightless Environment Training Facility

WIF - Water Immersion Facility

WRU - Work Restraint Unit

XTE - X-Ray Timing Explorer

# SERVICE SYSTEM PROGRAM REQUIREMENTS

## 1 - SERVICE SYSTEM PROGRAM REQUIREMENTS

- The satellite service system requirements shall be based on functions and operational tasks in support of three primary mission events: initial launch, revisits, and earth return. Within these mission events the applicable service functions, as shown in Fig. 1-1, shall be considered.

| MISSION EVENTS | NOMINAL SERVICE FUNCTIONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | DEPLOY | EXAM | RETRIEVAL | EARTH RETURN | CHECK-OUT | MAINT | RE-SUPPLY | RECONFIG |
| △ INITIAL LAUNCH | • | | | | • | | | |
| ○ REVISITS | • | • | • | | • | • | • | • |
| ▽ EARTH RETURN | | • | • | • | | | | |

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Fig. 1-1 Mission Events/Service Function Relationships

- Service requirements on or near the Orbiter (within a few kilometers) will be emphasized
- Requirements in the 1983-88 time frame receive primary consideration, although potential requirements in the 1988-93 time frame shall also be considered
- Equipment related requirements for crew and spacecraft interfaces shall be identified
- The service equipment shall be capable of being transported to and from orbit in the Space Shuttle Orbiter
- Service equipment shall be reusable and have multiple flight capability with appropriate between-flight maintenance as required
- Service equipment shall be standardized (to the extent practical) and designed for generic use with various classes of spacecraft

# SERVICE EQUIPMENT MISSION REQUIREMENTS

# 2 - SERVICE EQUIPMENT MISSION REQUIREMENTS

## 2.1 ON-ORBIT OPERATIONS

### 2.1.1 Standardization

Where practical, the on-orbit operations associated with initial launch, revisits, and earth return shall be performed using the same procedures and utilizing the same types of equipment.

### 2.1.2 Orbit Equipment

The servicing equipment shall operate at all LEO orbital inclinations and altitudes. The equipment design shall permit operations during both daylight and dark-side passes.

### 2.1.3 Operational Duration

Service equipment shall be capable of intermittent operation during 30-day space missions. Periodic maintenance shall extend operational life to ten years.

## 2.2 SATELLITE CLASSES

The satellite classes to be considered in formulating service equipment needs and requirements are shown in Fig. 2-1.

The satellite classes are defined as follows:

- Direct Delivery/Servicing — Those satellites capable of direct delivery to orbit and/or servicing by the Orbiter
- LEO/Propulsion — Those satellites whose LEO operational altitude is above the Orbiter's nominal delivery orbit
- GEO Satellites — Those satellites destined for GEO that are deployed in LEO by the Orbiter. Does not include DoD satellites

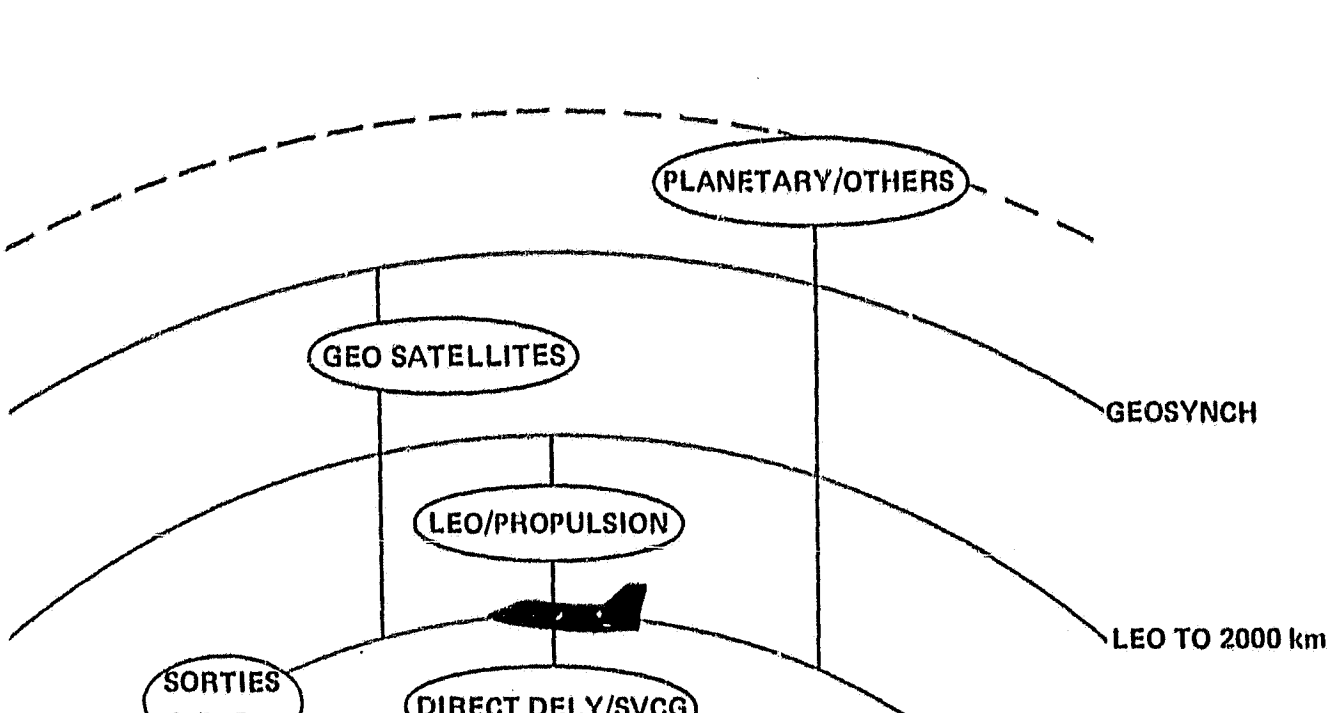


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Fig. 2-1 Satellite Classes

- Planetary/Others — Spacecraft destined for planetary missions that are deployed in LEO by the Orbiter. Additionally, undefinable satellite/payloads as might presently be carried as reflight opportunities in the STS manifest are also grouped herein

- Sorties/DoD — Sortie missions (e.g., Spacelab flights) and DoD Orbiter flights are grouped herein. To retain the unclassified nature of this study, only publicly-known information relating to DoD flights or payloads is carried in Grumman's Satellite User Model.

## 2.3 REFERENCE SATELLITE MISSIONS

The following satellite classes/spacecraft have been used as typical satellite references for supporting the development of servicing equipment requirements:

- Direct Delivery/Servicing
  - Gamma Ray Observatory (GRO)
  - Low Altitude Satellite Studies of Ionospheric Irregularities (LASSII)
  - Advanced X-Ray Astrophysics Facility (AXAF)
  - Earth Gravity Field Survey Mission (GRAVSAT)
- LEO/Propulsion
  - X-Ray Timing Explorer (XTE)
  - Landsat D'''
  - Upper Atmospheric Research Satellite (UARS)
  - National Oceanic Satellite System (NOSS)
- Geosynchronous
  - Simultaneous Astronomical Mission
  - Intelsat
- Orbital Debris
  - Orbiting Astronomical Observatory (OAO)
  - Solar Maximum Mission (SMM)
  - Large Debris.

# SERVICE EQUIPMENT USAGE AND REQUIREMENTS

# 3 - SERVICE EQUIPMENT USAGE AND REQUIREMENTS

## 3.1 EQUIPMENT IDENTIFICATION METHODOLOGY

### 3.1.1 Functional Analysis

Figure 3.1-1 illustrates the functional analysis methodology that was used to initially identify service needs and related crew and satellite interactions. Five reference satellites were analyzed:

- X-Ray Timing Explorer
- Upper Atmosphere Research Satellite

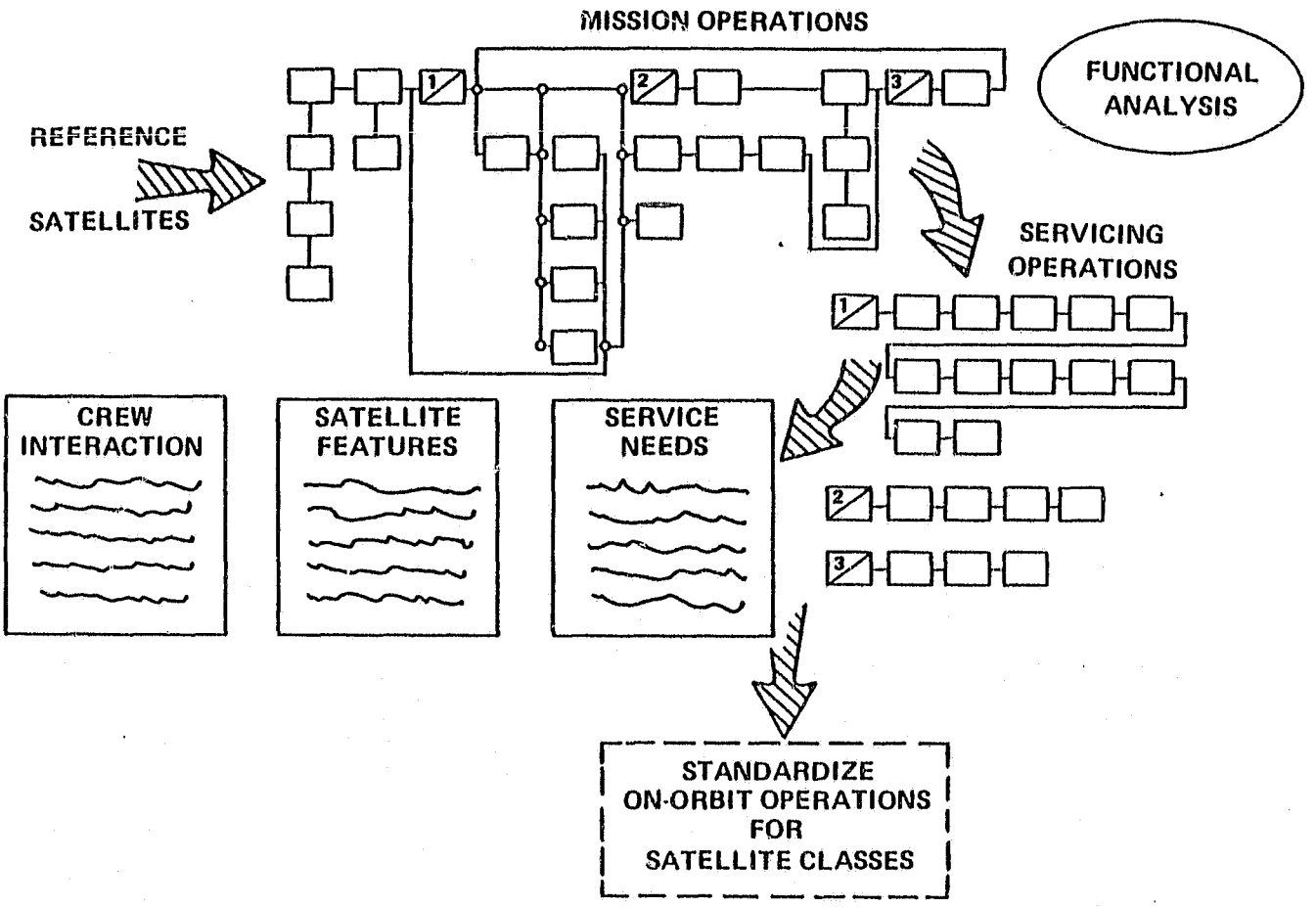


Fig. 3.1-1 Initial Methodology

- Advanced X-Ray Astrophysics Facility
- GRAVSAT A
- Orbiting Astronomical Observatory.

Appendix A contains the detailed functional analysis of the five reference satellites indicated. The analysis showed that the same or similar functions are needed for a number of different spacecraft. Consequently, the same items of servicing equipment could be designed to support a number of spacecraft.

These functional analyses suggested that standardization of on-orbit service operations and service equipment usage appears reasonable. We, therefore, turned our attention toward developing standardized, on-orbit servicing scenarios for the various satellite classes identified in our Satellite and Services User Model (S/SUM). The scenarios were then used as the basis for identifying service equipment needs and on-orbit usage.

### 3.1.2 Development of On-Orbit Operations Scenarios

Appendix B contains the compilation of on-orbit servicing scenarios that have been developed for initial launch, revisit, and earth return. In developing the on-orbit operations servicing scenarios, the following fundamental goals or objectives were sought:

- Standardize on-orbit service operations
  - e.g., checkout, servicing, deployment performed from a single Orbiter location
  - standardize satellite interfaces/checkout approach
- Maximize use of existing equipment and that under development
- Enhance utilization of STS to satellite users
  - Minimize service equipment user charges and cost of on-orbit operations
    - o Multipurpose equipment usage
    - o High equipment usage
    - o Minimize on-orbit service time
  - Maximize mission success prospects
    - o Satellites in fully operational condition before deployment
    - o Improved attitude/state vector information
    - o Sun-impingement protection with payload bay doors open
    - o Provide for orbital storage in event of malfunctions.

To accomplish these goals, our approach involved an examination of a broad spectrum of potential servicing scenarios to surface the likely service equipment needs. Within these scenarios are considerations of the following:

- Nominal*/alternate scenarios
- RMS inoperative situations
- Backups for hangup of mechanical devices
- Contamination-sensitive satellites; retrieval/servicing
- Orbiter plume impingement/satellite control implications during close proximity operations.

Additionally, the following assumptions were made in developing the on-orbit operations scenarios:

- Status monitoring, checkout, activation/deactivation of satellites is user controlled (satellite communications via Orbiter S-band or satellite's communications system, as appropriate)
- Minimize Orbiter status/checkout involvement
  - Power (as required)
  - Overall health (extent tbd, but standardized for all satellites)
  - Go/No-Go for deployment and servicing verification/effectiveness is satellite user decision
- Satellite deployment is via Orbiter command
- EVA is acceptable service mode
- MTV usage
  - Record LEO/GEO upper stage firings
  - Examine all satellites prior to Orbiter capture/berthing
- Compare RMS/tilt table (FSS cradle A') usage with RMS/Handling and Positioning Aid (HPA) for initial launch, revisit, and earth return
- Satellite separation $\Delta V$ during deployment imparted by RMS or HPA

---

*Nominal scenarios use existing service equipment such as Remote Manipulator Sys, Flight Support System Tilt Table, PAM-A, PAM-D, etc.

- Consider various close proximity operations
  - Orbiter closure
  - "Clean" vehicle closure from 1000 ft separation
  - Versatile Service Stage closure
    - o All unmanned vehicle closures are controlled by the Orbiter crew
- Orbiter safety considerations
  - Satellite RCS firings — >200 ft separation
  - Liquid rocket engine firings — >2700 ft separation
  - Solid rocket engine firings — OMS separation burn required to assure Orbiter exit of hazard envelope
- Uncooperative STS-era satellites assumed capturable via RMS/grapple techniques
  - High tumble rates assumed as "debris situation."

### 3.1.3 Service Equipment Identification Process

The overall methodology used in identifying the satellite service equipment is illustrated in Fig. 3.1-2. A matrix of servicing scenarios was initially developed for the primary mission events: initial launch, revisit, and earth return. Within the matrix were reflected the applicable satellite classes, nominal and alternate modes of operation, contingency situations (as RMS inoperative), and potential close proximity operations. Level-1 on-orbit operations scenarios, representing sequences-of-events, were developed for a sufficient number of cases in each servicing scenarios matrix in order to reasonably project equipment usage for the total matrix. Over twenty percent of the 180 scenarios considered within the matrix of mission events were developed in sequence-of-events fashion. The final step involved a compilation of the equipment utilization for each of the scenarios represented in the initial launch, revisit, and earth return matrices. The service equipment identification process, reported herein, was supported by Grumman's Independent Research and Development (IRAD) efforts.

## 3.2 SERVICE EQUIPMENT USAGE ANALYSIS

### 3.2.1 Initial Launch

Figure 3.2-1 shows the matrix of initial launch scenarios considered in the study and identifies thirty-four scenarios potentially applicable for deployment. The sce-

narios noted with numerical designations (e.g., D1, D2, etc.) represent those for which Level 1 sequences-of-events were prepared and are provided in Appendix B.

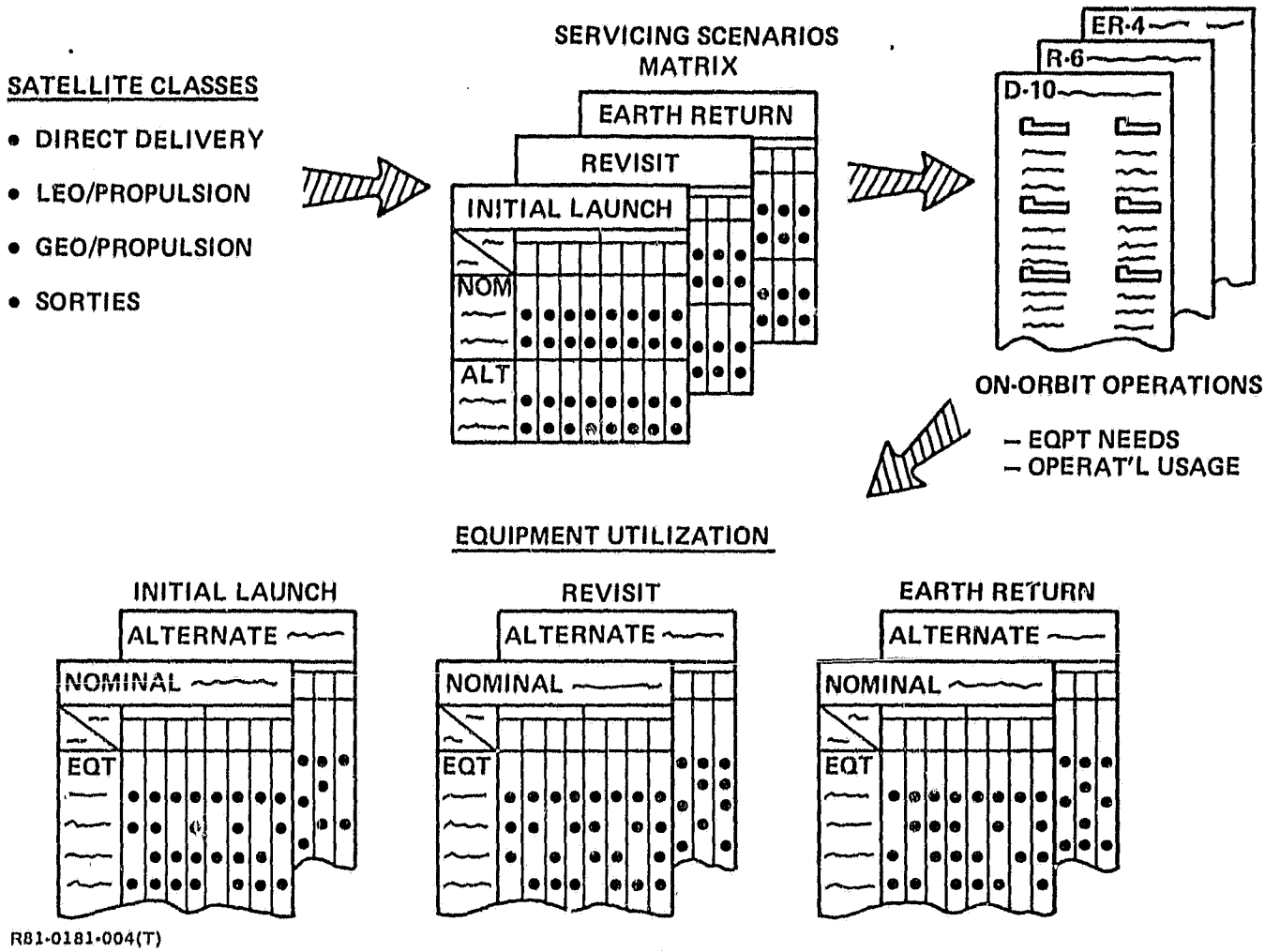


**Fig. 3.1-2 Service Equipment Identification Process**

The Direct Delivery class payloads consider both multiple Orbiter payload deployments and a single large payload (e.g., Space Telescope and Advanced X-Ray Astrophysics Facility (AXAF)). The LEO/Propulsion satellite class includes an integral propulsion stage (as applicable to MMS-type satellites) and a Versatile Service Stage (e.g., Teleoperator Maneuvering System (TMS)) with two options: stage mating on the ground and stage mating on-orbit. The GEO/Propulsion class includes considerations of solid and liquid upper stages, the solids reflecting usage of IUS, PAM-A, and PAM-D. The deployment scenarios also consider nominal and alternate cases, RMS inoperative situations, and the applicable close proximity operations. (The VSS is the active vehicle returning/closing with the Orbiter after delivering a satellite to its operational orbit.) Nominal scenarios reflect use of existing equipment as RMS and the FSS Cradle A' Tilt Table; alternate scenarios reflect usage of the RMS in conjunction with a Handling and

Positioning Aid (HPA). Additionally, all scenarios include backups for hangup of mechanical devices.

### 3.2.1.1 Nominal Initial Launch Scenarios - RMS and/or RMS/Tilt Table Usage

The nominal series of scenarios, referred to in the Initial Launch-Deployment Scenarios matrix (Fig. 3.2-1), represents scenarios in which the RMS is used to deploy payloads from the Orbiter, and/or serves to support a deployment operation involving a Tilt Table (e.g., FSS Cradle A') or payload deployment devices as PAM-A and D. As shown in the Initial Launch-Deployment Scenarios matrix, eleven Level-1 sequences-of-events were prepared (D-1, D-2, D-5, D-6, D-13, D-9, D-11, D-15, D-16, D-17, D-18) to aid in surfacing equipment utilizations. The D1 and D2 scenarios are highlighted in Fig. 3.2-1 as they will be addressed further to illustrate the technique used to identify service equipments/usage.

34 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY | | LEO/PROPULSION | | | GEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | VERSATILE SERVICE STAGE | | SOLID STAGES | | | LIQ STAGE |
| | MULTIPLE PAYLOADS | LARGE PAYLOAD | INTEGRAL PROPULSION STAGE | STG MATING ON GRD | STG MATING ON ORBIT | IUS | PAM-A SPINNER | PAM-D SPINNER | TBD |
| • NOMINAL (RMS AND/OR RMS/ TILT TABLE USAGE) | D-1 | D-5 | D-13 | D-9 | D-11 | D-15 D-16 | D-17 | D-18 | ● |
| • RMS INOPERATIVE | D-2 | D-6 | ● | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | NONE | | | "CLEAN" VSS CLOSES | | NONE | | | |
| • ALTERNATE (RMS/HPA USAGE) | D-3 | D-7 | D-14 | D-10 | D-12 | ● | D-19 | | ● |
| • RMS INOPERATIVE | D-4 | D-8 | ● | ● | ● | ● | ● | | ● |
| CLOSE PROXIMITY OPS | NONE | | | "CLEAN" VSS CLOSES | | NONE | | | |

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D-N = SCENARIOS COMPLETED

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**Fig. 3.2-1 Initial Launch – Deployment Scenarios (all scenarios include backups for hangup of mechanical devices)**

Figure 3.2-2 illustrates a simplified form of the D1 Level-1 on-orbit sequence-of-events for the direct delivery payload class, multiple payload deployment, and primary RMS usage situation. The service equipment needs associated with a particular event shown in the figure are highlighted. Note that the first event calls for:

- Retention Structure
- Remote Manipulator System (RMS)
- AFD Controls/Displays for satellite checkout.

The backup situations have also identified equipment needs, namely:

- Manipulator Foot Restraint (MFR) to cover retention latch hangups
- MMU/WRU with a stabilizer attachment to assist a potential satellite appendage hangup.

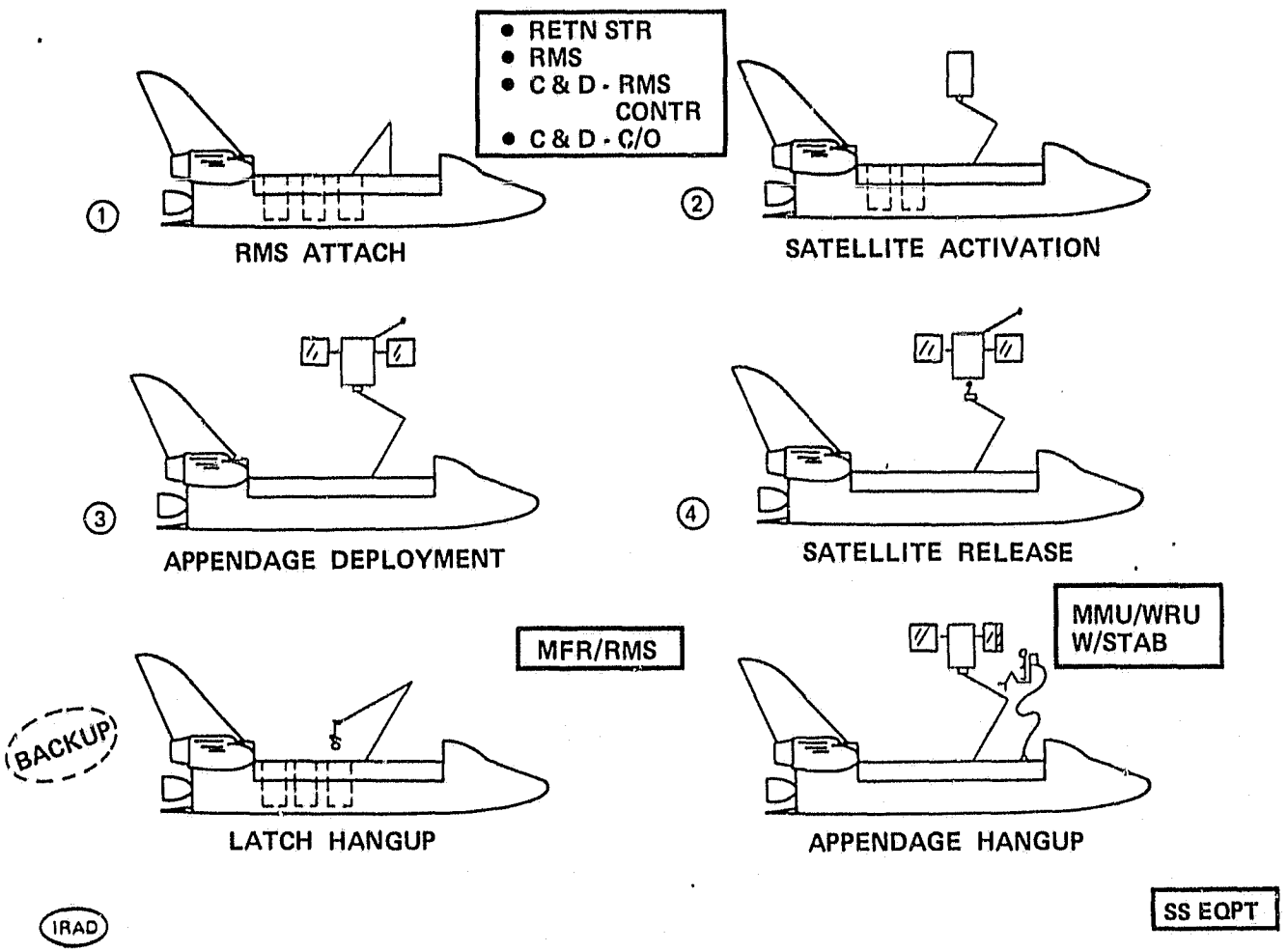


Fig. 3.2-2 D1 Initial Launch Sequence — Direct Delivery Payload Class — Multiple Payloads — RMS Usage

The equipment usage segment of the nominal scenario (RMS and/or RMS and tilt table usage) addressing the D-1 scenario is highlighted in Fig. 3.2-3, within the overall format being used to identify equipment utilization for all the scenarios applicable to this nominal (RMS and/or RMS and Tilt Table usage) case. The Level-1 sequence-of-events identifies the primary and backup service equipment needed for the D-1 scenario. Additionally, optional service equipment is also applicable, at the discretion of the satellite user. This optional equipment consists of:

- Sun Shield - to provide solar impingement protection to a satellite with the Orbiter's payload bay doors open
- Orbital Storage - to enable the satellite user to leave the spacecraft on orbit for subsequent revisit/repair in the event of a malfunction detected prior to deployment. The orbital storage mode obviates the need to return the satellite to earth and relaunch, incurring additional launch costs

(D-1)

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY | | LEO/PROPULSION | | | GEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | VERSATILE SERVICE STAGE | | SOLID STAGES | | | LIQ STAGE |
| | MULTIPLE PAYLOADS | LARGE PAYLOAD | INTEGRAL PROPULSION STAGE | STG MATING ON GRD | STG MATING ON ORBIT | IUS | PAM-A SPINNER | PAM-D SPINNER | TBD |
| **NOMINAL** | | | | | | | | | |
| • RETENTION STRUCTURE | ● | | | | | | | | |
| • TILT TABLE | | | | | | | | | |
| • SPIN TABLE | | | | | | | | | |
| • PIDA | | | | | | | | | |
| • RMS | ● | | | | | | | | |
| • MFR/RMS | ○ * | | | | | | | | |
| • MMU/WRU { • W/END EFFECT • W/STABILIZER } | ○ | | | | | | | | |
| • HPA | | | | | | | | | |
| • MTV | | | | | | | | | |
| • VSS – W/DELY/RENDEZ | | | | | | | | | |
| • AFD – C&D { W/RMS ● ; W/C'KOUT ● ; W/CL PROX CONT } | | | | | | | | | |
| **OPTIONAL** | | | | | | | | | |
| • SUN SHIELD | ● | | | | | | | | |
| • ORBITAL STORAGE | ● √ | | | | | | | | |
| • ATTITUDE TRANSFER PKG | ● | | | | | | | | |
| • LIGHTING ENHANCEMENT | ○ | | | | | | | | |

CODE: ● PRIME USAGE ○ BACKUP ○² SECOND MMU/WRU REQD ○—○ / ●—○ ONE UNIT REQD √ MMU/WRU REQD * EVA VIA HANDRAILS OPTIONAL

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Fig. 3.2-3 D1 – Initial Launch – Equipment Utilization Summary – RMS and/or RMS/Tilt Table Usage

- Attitude Transfer Package - to provide improved attitude and state vector information to the satellite
- Lighting Enhancement needs could apply in all situations involving EVA; thus, where EVA is shown as a backup need (with MFR/RMS, for example) it is also reflected as a backup in the optional equipment category.

Figure 3.2-4 is identical to Fig. 3.2-1 but now highlights the strip of ten individual scenarios applicable to the nominal (RMS and/or RMS/Tilt Table usage) scenarios. This is done to further illustrate the equipment identification technique and to acquaint the reader with the format for the equipment utilization summary charts that follow in this report.

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY | | LEO/PROPULSION | | | GEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | VERSATILE SERVICE STAGE | | SOLID STAGES | | | LIQ STAGE |
| | MULTIPLE PAYLOADS | LARGE PAYLOAD | INTEGRAL PROPULSION STAGE | STG MATING ON GRD | STG MATING ON ORBIT | IUS | PAM-A SPINNER | PAM-D SPINNER | TBD |
| • NOMINAL (RMS AND/OR RMS TILT TABLE USAGE) | D-1 | D-5 | D-13 | D-9 | D-11 | D-15 D-16 | D-17 | D-18 | ● |
| • RMS INOPERATIVE | D-2 | D-6 | ● | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | NONE | | | "CLEAN" VSS CLOSES | | NONE | | | |
| • ALTERNATE (RMS/HPA USAGE) | D-3 | D-7 | D-14 | D-10 | D-12 | ● | D-19 | | ● |
| • RMS INOPERATIVE | D-4 | D-8 | ● | ● | ● | ● | ● | | ● |
| CLOSE PROXIMITY OPS | NONE | | | "CLEAN" VSS CLOSES | | NONE | | | |

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D-N = SCENARIOS COMPLETED

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Fig. 3.2-4 Initial Launch – Deployment Scenarios – Nominal Scenario Emphasis – RMS and/or RMS/Tilt Table Usage
(all scenarios include backups for hangup of mechanical devices)

Figure 3.2-5 now shows the equipment utilization summary that reflects the service equipment usage for the nominal ten scenarios highlighted in Fig. 3.2-4. In addition, the Level-1 sequence-of-events (e.g., D-1, D-5, etc.), which were prepared to surface the equipment identifications, are also identified on the figure. Their equipment utilizations can be correlated with the scenarios found in Appendix B.

Figure 3.2-5 identifies the nominal, optional, and backup service equipment applicable to these initial launch scenarios for the satellite classes/categories shown, wherein the principal equipment usage involves an RMS and/or FSS Cradle A' Tilt Table. Note that an MFR/RMS appears as a backup for all scenarios, although EVA via handrails could also be used. The MMU/WRU with stabilizer adaption appears on four scenarios. In consonance with our original assumptions, an MTV is deployed to view and record all propulsion stage firings and thus appears on seven scenarios. Exclusive of AFD

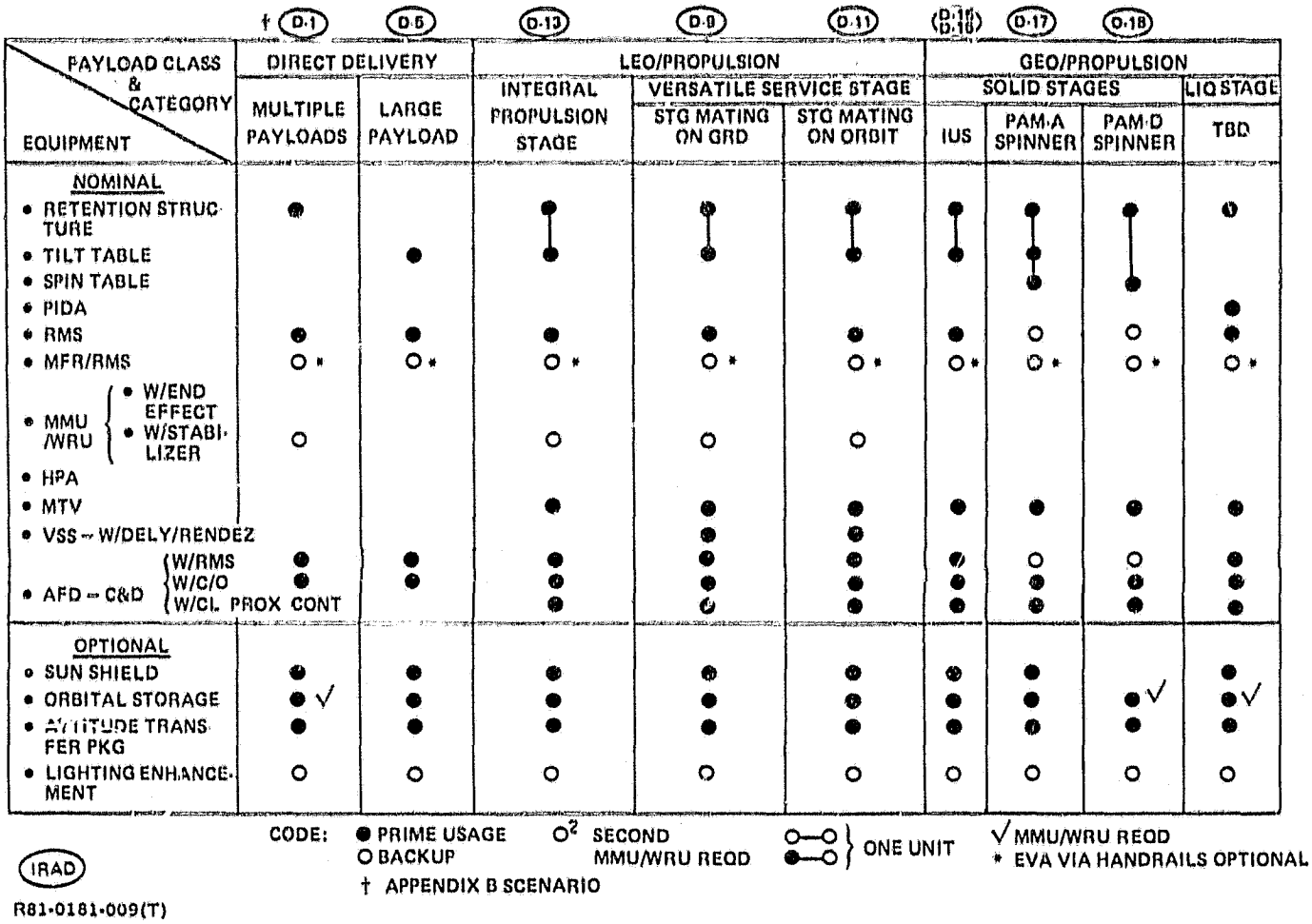


Fig. 3.2-5 Initial Launch — Equipment Utilization Summary — Nominal Scenario — RMS and/or RMS/Tilt Table Usage

Controls/Displays and optional equipment, between three and six items of service equipment are needed to cover these initial launch scenarios.

Figure 3.2-6 illustrates the simplified form of the D-2 Level-1 on-orbit sequence-of-events for the direct delivery payload class, multiple payload deployment, with an RMS-inoperative situation. The service equipment needs associated with a particular event shown in the figure are highlighted. Note that the first event calls for:

- Retention Structure
- MMU/WRU with RMS end effector adaption
- AFD Controls/Displays for satellite checkout.

The backup situations have also identified equipment needs, namely:

- MMU/WRU with stabilizer to cover retention latch hangups, or EVA via handrails could be employed
- A second MMU/WRU with stabilizer which would be needed to assist a potential satellite appendage hangup while the first MMU/WRU with end effector maintains the stability of the satellite.

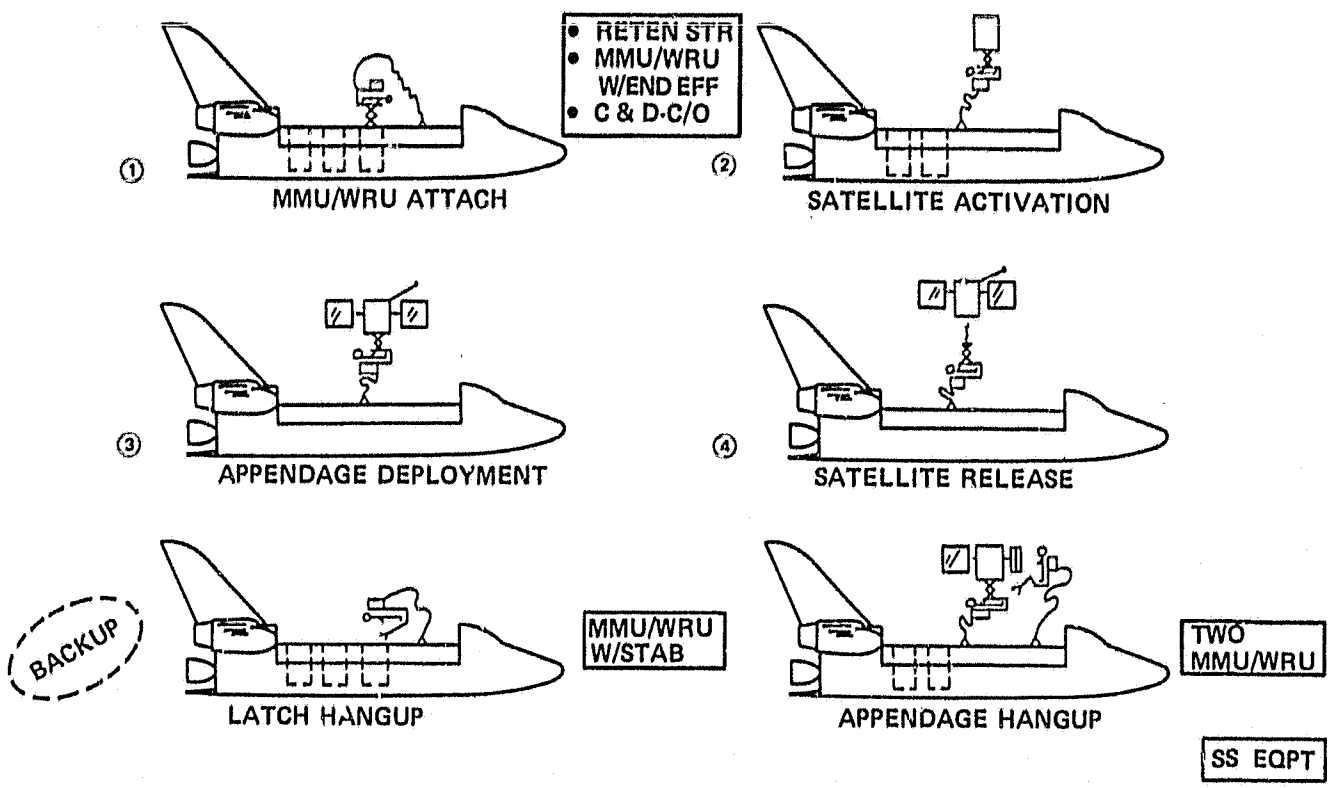


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Fig. 3.2-6 D2 – Nominal Initial Launch Scenario – Direct Delivery Payload Class – Multiple Payloads – RMS Inoperative

The equipment usage segment of the D-2 RMS-inoperative scenario is highlighted in Fig. 3.2-7. Note that a second MMU/WRU would be needed to also support the orbital storage option. However, since the nominal equipment complement would contain two MMU/WRUs, the orbital storage option could be accomplished within the basic scenario's complement of equipment.

D-2

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY | | LEO/PROPULSION | | | GEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|---|---|
| | MULTIPLE PAYLOADS | LARGE PAYLOAD | INTEGRAL PROPULSION STAGE | VERSATILE SERVICE STAGE | | SOLID STAGES | | | LIQ STAGE |
| | | | | STG MATING ON GRD | STG MATING ON ORBIT | IUS | PAM-A SPINNER | PAM-D SPINNER | TBD |
| **NOMINAL** | | | | | | | | | |
| • RETENTION STRUCTURE | ● | | | | | | | | |
| • TILT TABLE | | | | | | | | | |
| • SPIN TABLE | | | | | | | | | |
| • PIDA | | | | | | | | | |
| • RMS | | | | | | | | | |
| • MFR/RMS | | | | | | | | | |
| • MMU/WRU (* W/END EFFECT, • W/STABILIZER) | ●, $O^2$ | | | | | | | | |
| • HPA | | | | | | | | | |
| • MTV | | | | | | | | | |
| • VSS – W/DELY/RENDEZ | | | | | | | | | |
| • AFD – C&D (W/RMS, W/C'KOUT, W/CL PROX CONT) | ● | | | | | | | | |
| **OPTIONAL** | | | | | | | | | |
| • SUN SHIELD | ● | | | | | | | | |
| • ORBITAL STORAGE | ●√√ | | | | | | | | |
| • ATTITUDE TRANSFER PKG | ● | | | | | | | | |
| • LIGHTING ENHANCEMENT | ●—O | | | | | | | | |

CODE: ● PRIME USAGE, O BACKUP, * EVA VIA HANDRAILS OPTIONAL, $O^2$ SECOND MMU/WRU REQD, ●—O / O—O ONE UNIT REQD, √ MMU/WRU REQD, √√ SECOND MMU/WRU REQD

IRAD

R81-0181-011(T)

Fig. 3.2-7 D2 – Initial Launch – Equipment Utilization Summary – Nominal Scenario – RMS and/or RMS/Tilt Table Usage – RMS Inoperative

Figure 3.2-8 now highlights the strip of nine individual scenarios applicable to this RMS-inoperative situation for the various satellite classes/categories shown in the original initial launch deployment scenarios matrix (Ref: Fig. 3.2-1).

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY | | LEO/PROPULSION | | | GEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | VERSATILE SERVICE STAGE | | SOLID STAGES | | | LIQ STAGE |
| | MULTIPLE PAYLOADS | LARGE PAYLOAD | INTEGRAL PROPULSION STAGE | STG MATING ON GRD | STG MATING ON ORBIT | IUS | PAM-A SPINNER | PAM-D SPINNER | TBD |
| • NOMINAL (RMS AND/OR RMS TILT TABLE USAGE) | D-1 | D-5 | D-13 | D-9 | D-11 | D-15 D-16 | D-17 | D-18 | ● |
| • RMS INOPERATIVE | D-2 | D-6 | ● | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | NONE | | | "CLEAN" VSS CLOSES | | NONE | | | |
| • ALTERNATE (RMS/HPA USAGE) | D-3 | D-7 | D-14 | D-10 | D-12 | ● | D-19 | | ● |
| • RMS INOPERATIVE | D-4 | D-8 | ● | ● | ● | ● | ● | | ● |
| CLOSE PROXIMITY OPS | NONE | | | "CLEAN" VSS CLOSES | | NONE | | | |

IRAD

D-N = SCENARIOS COMPLETED

R81-0181-012(T)

Fig. 3.2-8 Initial Launch – Deployment Scenarios – Nominal Scenario – RMS and/or RMS/Tilt Table Usage – RMS Inoperative Emphasis
(all scenarios include backups for hangup of mechanical devices)

Figure 3.2-9 reflects the equipment utilization summary for the strip of nine individual scenarios highlighted in Fig. 3.2-8. Also identified are the Level-1 sequences-of-events (e.g., D-2, D-6) which were prepared to surface the equipment identification. The figure identifies the nominal, optional, and backup service equipment applicable to these RMS-inoperative initial launch scenarios for the satellite classes/categories shown. Note that the MMU/WRU adaptations have replaced both the RMS and MFR/RMS functions previously shown in the RMS usage situation (Ref: Fig. 3.2-5). Note, also, that a second MMU/WRU with stabilizer is needed for four of the scenarios shown. Exclusive of AFD Controls/Displays and optional equipment, between two and five items of service equipment are needed to cover these initial launch scenarios.

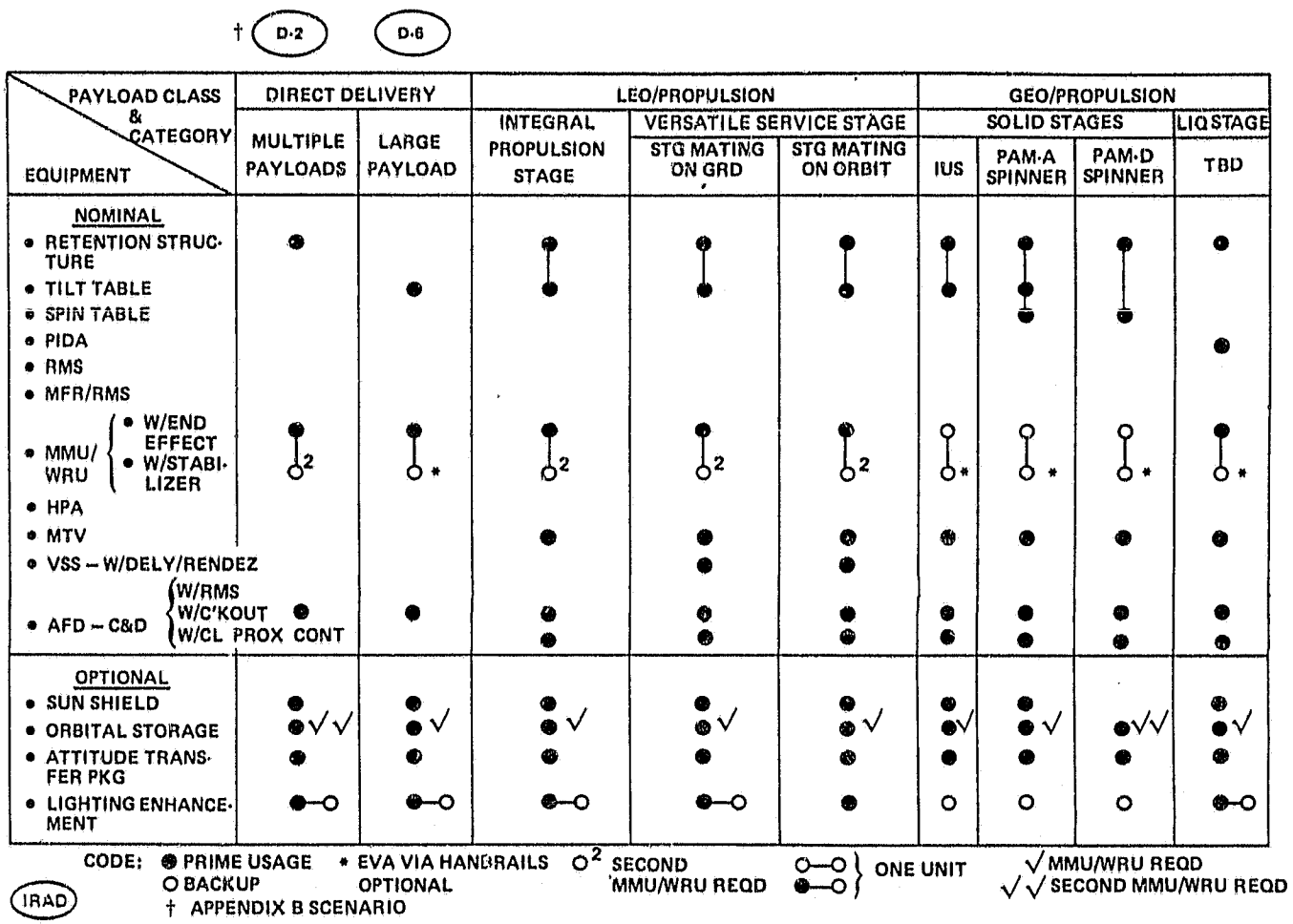


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Fig. 3.2-9 Initial Launch – Equipment Utilization Summary – Nominal Scenario -- RMS and/or RMS/Tilt Table Usage – RMS Inoperative

### 3.2.1.2 Alternate Initial Launch Scenarios - RMS/HPA Usage

The alternate series of scenarios referred to in the Initial Launch-Deployment Scenarios matrix (Fig. 3.2-1) represents scenarios where the RMS serves to support deployment operations involving a Handling and Positioning Aid (HPA), or payload deployment devices as PAM-A and -D. In these scenarios is shown in Fig. 3.2-10 and dard location" from which satellite checkout is performed and from which the satellite is deployed. As shown in the Initial Launch-Deployment matrix, eight Level-1 sequences-of-events were prepared (D-3, D-4, D-7, D-8, D-14, D-10, D-12, D-19) to aid in surfacing equipment utilizations.

The equipment usage for these alternate scenarios is shown in Fig. 3.2-10 and 3.2-11. Figure 3.2-10 shows the equipment complements for the eight individual scenarios wherein the RMS and HPA are prime service equipment. The figure identifies the

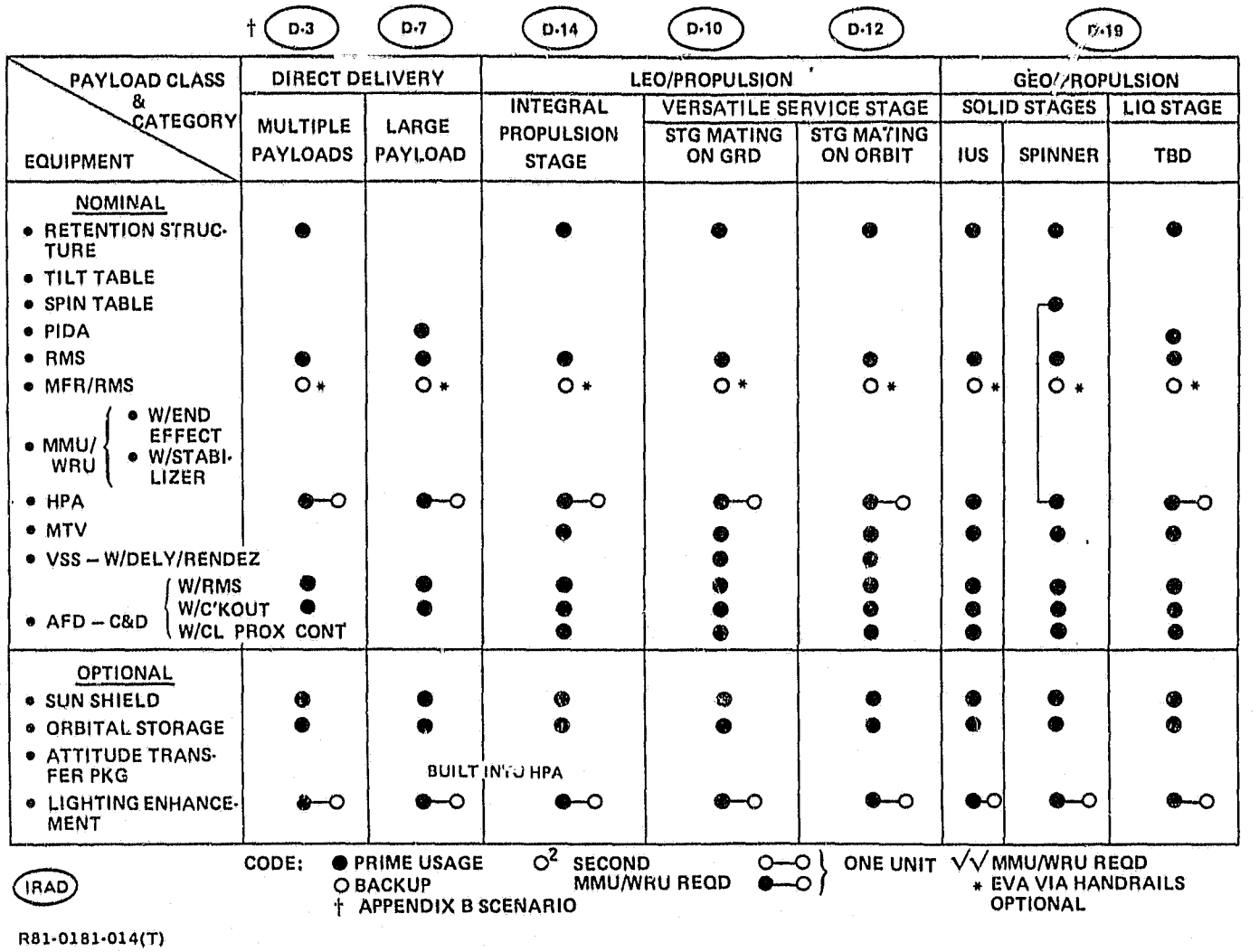


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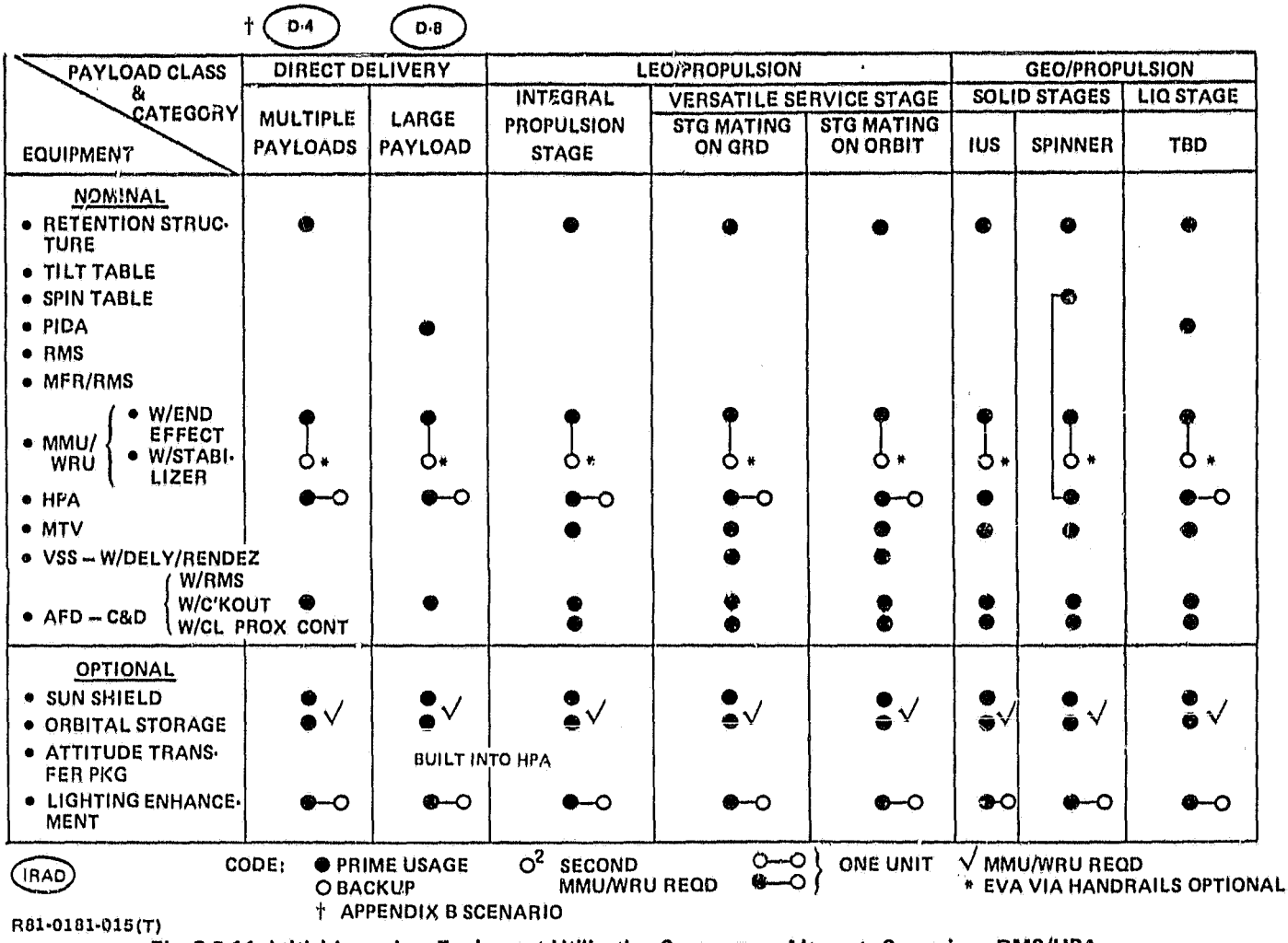
Fig. 3.2-10 Initial Launch – Equipment Utilization Summary – Alternate Scenario – RMS/HPA Usage




R81-0181-015(T)

**Fig. 3.2-11 Initial Launch – Equipment Utilization Summary – Alternate Scenario – RMS/HPA Usage – RMS Inoperative**

nominal, optional, and backup service equipment applicable for the satellite classes/categories shown. The figure also identifies the Level-1 sequences-of-events (e.g., D-3, D-7, etc.) that were prepared to surface the equipment identifications shown. Exclusive of AFD Controls/Displays and optional equipment, between four and six items of service equipment are needed to cover these initial launch scenarios.

Note that in the previous equipment identifications for the Nominal scenarios (RMS and/or RMS/Tilt Table usage), an Attitude Transfer Package was identified as an item of optional equipment to provide improved attitude/state vector information to satellites. For scenarios that utilize an HPA, however, the attitude transfer function is built into the HPA.

Figure 3.2-11 shows the equipment usage for the eight individual scenarios wherein the RMS/HPA are the planned prime service usage equipment, and the RMS is inopera-

tive. The figure again identifies the nominal, optional, and backup service equipment applicable for the satellite classes/categories shown. It also identifies the Level-1 sequences-of-events (e.g., D-4, D-8) that were prepared to assist in surfacing the equipment identifications noted therein. Note that in this RMS-inoperative situation, the MMU/WRU adaptations have again replaced both the RMS and MFR/RMS functions shown in the RMS-inoperative case (Ref: Fig. 3.2-10). Also note, however, that in this HPA usage situation, a single MMU/WRU is needed as contrasted with the Tilt Table usage case (Fig. 3.2-9) where two MMU/WRUs are called for. Exclusive of AFD Controls/Displays and optional equipment, between three and five items of service equipment are needed to cover these initial launch scenarios.

### 3.2.1.3 Summary of Initial Launch Service Equipment and Usage

Figure 3.2-12 consolidates the equipment utilization summaries that apply to the 34 scenarios considered in the Initial Launch-Deployment Scenarios matrix. A total of 17 service equipment needs have been identified for initial launch to cover the matrix of applicable scenarios shown in Fig. 3.2-12. Thirteen of the equipment needs represent nominal (or basic) equipment that would be carried in the satellite operations. Four of the identified equipment needs represent optional equipment/services that could be made available to the satellite user community. The service equipment needs identified are as follows:

Nominal Equipment Needs

(1) Retention Structure — Satellite retention can be satisfied by an integral structure built into the satellite, the Flight Support System (FSS) which is adaptable to MMS-type (or configuration) payloads, or by mounting payloads in Spacelab pallets. Payload retention latches should be designed for back-up manual release; following release they should maintain the satellite in a "caged" condition to enable RMS attachment for deployment (if applicable).

(2) Tilt Table — This deployment capability can be satisfied by the FSS Cradle A' and is also available for Inertial Upper Stage (IUS) and PAM A payloads.

| | | |
|---|---|---|
| (3) | Spin Table | Spin capabilities for deployment can be provided for PAM A and PAM D payloads, and can also be accommodated on the Handling and Positioning Aid (HPA). |
| (4) | Payload Installation and Deployment Aid (PIDA) | Enables deployment (and re-installation) from the payload bay of very large size/mass payloads (e.g., 15 ft diameter and 65,000 lb) without exceeding the 3.0 inch Orbiter clearance envelope. |
| (5) | Remote Manipulator System (RMS) | The RMS can be used to deploy payloads from the Orbiter payload bay, provided that the satellites contain an RMS-compatible grapple fixture. The RMS will release a satellite with essentially no differential velocity during deployment. It should be noted, however, that most of our operational scenarios call for satellites to be released by the RMS with a $\Delta V$ of about 1 ft/sec -- a capability for which the RMS has not been nominally designed. |
| (6) | Manipulator Foot Restraint (MFR)/RMS | The MFR/RMS serves as a backup for potential hangup of retention latches, mechanical hangup situations associated with satellite appendage deployment, and for EVA support of sortie missions. |
| (7) | Manned Maneuvering Unit/ Work Restraint Unit (MMU/WRU) | Adaptations of the WRU in conjunction with the MMU serve as the backup for RMS-inoperative situations for initial launch/deployment. A WRU adapted with an RMS snare end-effector would remove a satellite from the payload bay and deploy it with a $\Delta V$ of about 1 ft/sec. A WRU adapted with a stabilizer could serve to support hangups of retention latches and similar situations associated with appendage deployment of satellites. |

34 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY | | LEO/PROPULSION | | | GEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | VERSATILE SERVICE STAGE | | SOLID STAGES | | | LIQ STAGE |
| | MULTIPLE PAYLOADS | LARGE PAYLOAD | INTEGRAL PROPULSION STAGE | STG MATING ON GRD | STG MATING ON ORBIT | IUS | PAM A SPINNER | PAM D SPINNER | TBD |
| • NOMINAL (RMS AND/OR RMS TILT TABLE USAGE) | D-1 | D-5 | D-13 | D-9 | D-11 | D-15 D-16 | D-17 | D-18 | ● |
| • RMS INOPERATIVE | D-2 | D-6 | ● | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | NONE | | "CLEAN" VSS CLOSES | | | NONE | | | |
| • ALTERNATE (RMS/HPA USAGE) | D-3 | D-7 | D-14 | D-10 | D-12 | ● | D-19 | | ● |
| • RMS INOPERATIVE | D-4 | D-8 | ● | ● | ● | ● | ● | | ● |
| CLOSE PROXIMITY OPS | NONE | | "CLEAN" VSS CLOSES | | | NONE | | | |

D N = SCENARIOS COMPLETED

INITIAL LAUNCH – DEPLOYMENT SCENARIOS MATRIX

IRAD

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FOLDOUT FRAME

## NOMINAL SCENARIO

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | † D-1 DIRECT DELIVERY: MULTIPLE PAYLOADS | D-5 DIRECT DELIVERY: LARGE PAYLOAD | D-13 LEO/PROPULSION: INTEGRAL PROPULSION STAGE | D-9 LEO/PROPULSION: VERSATILE SERVI… STG MATING ON GRD | ST… |
|---|---|---|---|---|---|
| NOMINAL | | | | | |
| • RETENTION STRUCTURE | ● | | ● | ● | |
| • TILT TABLE | | ● | ● | ● | |
| • SPIN TABLE | | | | | |
| • PIDA | | | | | |
| • RMS | ● | ● | ● | ● | |
| • MFR/RMS | ○ • | ○ • | ○ • | ○ • | |
| • MMU /WRU { • W/END EFFECT • W/STABILIZER | ○ | | ○ | ○ | |
| • HPA | | | | | |
| • MTV | | | ● | ● | |
| • VSS – W/DELY/RENDEZ | | | | ● | |
| • AFD – C&D { W/RMS W/C/O W/CL PROX CONT | ● ● | ● ● | ● ● ● | ● ● ● | |
| OPTIONAL | | | | | |
| • SUN SHIELD | ● | ● | ● | ● | |
| • ORBITAL STORAGE | ● ✓ | ● | ● | ● | |
| • ATTITUDE TRANSFER PKG | ● | ● | ● | ● | |
| • LIGHTING ENHANCEMENT | ○ | ○ | ○ | ○ | |

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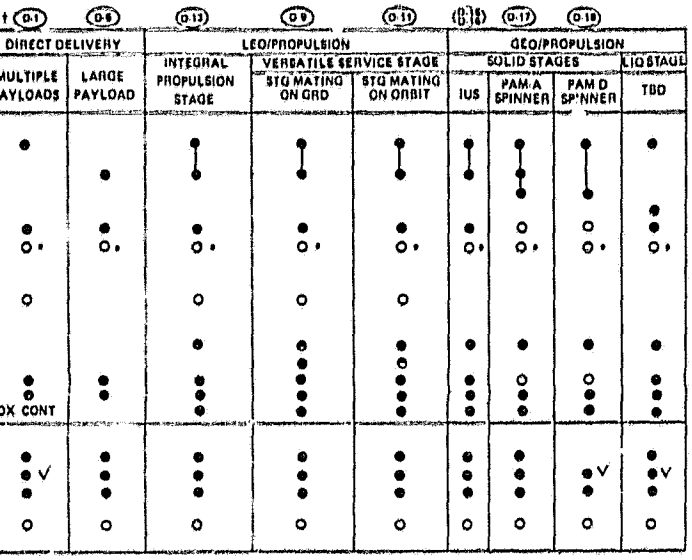
– RMS AND/OR RMS/TILT TA

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | † D-2 DIRECT DELIVERY: MULTIPLE PAYLOADS | D-6 DIRECT DELIVERY: LARGE PAYLOAD | LEO/PROPULSION: INTEGRAL PROPULSION STAGE | LEO/PROPULSION: VERSATILE SERVI… STG MATING ON GRD | ST… |
|---|---|---|---|---|---|
| NOMINAL | | | | | |
| • RETENTION STRUCTURE | ● | | ● | ● | |
| • TILT TABLE | | ● | ● | ● | |
| • SPIN TABLE | | | | | |
| • PIDA | | | | | |
| • RMS | | | | | |
| • MFR/RMS | | | | | |
| • MMU/WRU { • W/END EFFECT • W/STABILIZER | ● ○2 | ● ○ • | ● ○2 | ● ○2 | |
| • HPA | | | | | |
| • MTV | | | ● | ● | |
| • VSS – W/DELY/RENDEZ | | | | ● | |
| • AFD – C&D { W/RMS W/C'KOUT W/CL PROX CONT | ● | ● | ● ● | ● ● | |
| OPTIONAL | | | | | |
| • SUN SHIELD | ● | ● | ● | ● | |
| • ORBITAL STORAGE | ●✓✓ | ●✓ | ●✓ | ●✓ | |
| • ATTITUDE TRANSFER PKG | ● | ● | ● | ● | |
| • LIGHTING ENHANCEMENT | ●–○ | ●–○ | ●–○ | ●–○ | |

R81-0181-013(T)

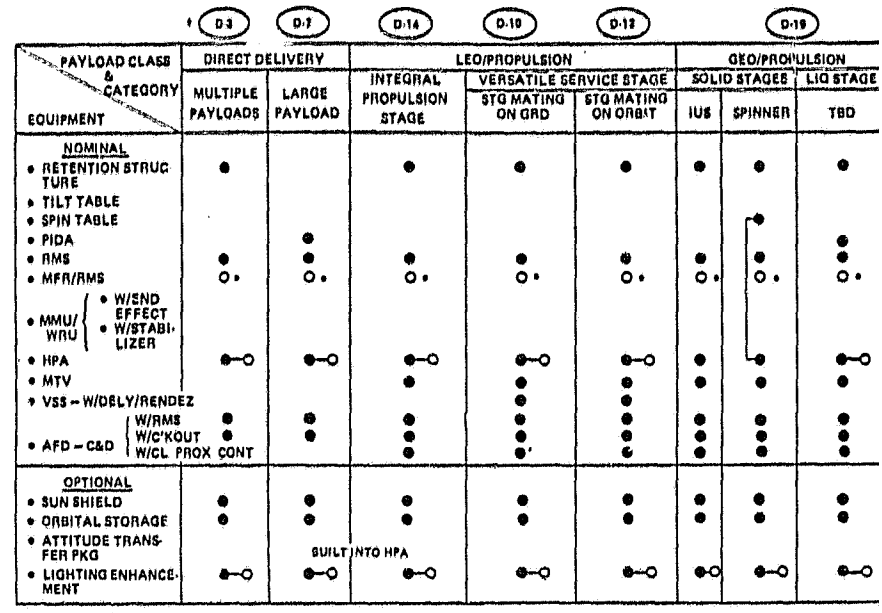
– RMS AND/OR RMS TILT T…
– RMS INOPERATIVE

## NOMINAL SCENARIO

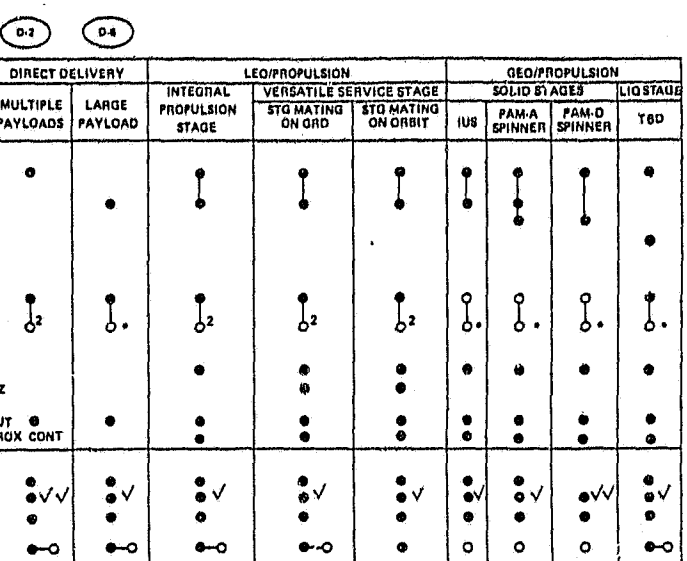



– RMS AND/OR RMS/TILT TABLE USAGE

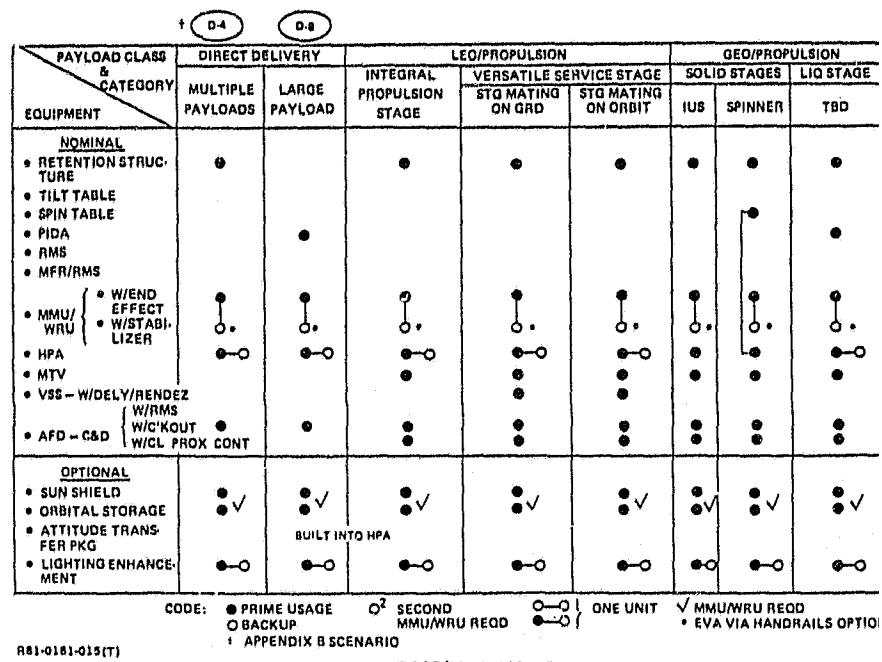
## ALTERNATE SCENARIO




– RMS/HPA USAGE




– RMS AND/OR RMS TILT TABLE USAGE
– RMS INOPERATIVE




– RMS/HPA USAGE
– RMS INOPERATIVE

Fig. 3.2-12 Service Equipment Utilization for Initia Launch Scenarios: Nominal Scenario; Alternate Scenario

2 FOLDOUT FRAME

| | |
|---|---|
| (8) Handling and Positioning Aid (HPA) | The HPA will support satellites outside the confines of the payload bay and, with its "over-the side" feature, could enable full deployment of satellite appendages (if desired) prior to release from the Orbiter. It contains a standardized berthing and umbilical interface for initial checkout prior to deployment, has provisions for an attitude/state vector transfer for all satellites, and provides the means to impart a $\Delta V$ to a satellite to effect Orbiter separation. Additionally, a spin table capability can also be accommodated. |
| (9) Maneuverable Television (MTV) | For initial launch/deployment, the MTV can be deployed to view and record propulsion stage firings of satellites destined for higher LEO altitudes and GEO. |
| (10) Versatile Service Stage (VSS):<br>• Delivery/Rendezvous Capability | The VSS is used to transfer satellites to higher energy LEO orbits. Following satellite placement, the VSS would return to the Orbiter and rendezvous within about 1000 ft. The close proximity flight control to RMS capture of the VSS is remotely controlled by the Orbiter crew. |
| (11-13) Aft Flight Deck-Controls & Displays (AFD-C&D):<br>• RMS Control Panel<br>• Satellite C/O Panel<br>• Close Proximity Ops Panel | Controls and displays will be provided in the AFD for control of the RMS, for standardized satellite checkout and deployment, and for close proximity flight control of the MTV and Versatile Service Stage. |

Optional Equipment

| | |
|---|---|
| (14) Sun Shield | This equipment provides solar impingement protection to a satellite with the Orbiter's payload bay doors open and is modularly adaptable to accommodate varying length satellite payloads. |
| (15) Orbital Storage | Provides the satellite user with the option to leave the spacecraft on-orbit for subsequent revisit/repair in the event of a malfunction detected prior to deployment that would categorize the satellite as nonoperational. |
| (16) Attitude Transfer Package | This unit provides a means for accurately transferring attitude reference data from the Orbiter nav-base to satellites requiring accurate attitude/position information prior to deployment. |
| (17) Lighting Enhancement | Supplementary lighting or enhanced viewing capabilities are provided for backup EVA activities potentially associated with satellite deployment. |

### 3.2.2 Revisit

Figure 3.2-13 shows the matrix of revisit scenarios considered in the study and identifies forty-eight scenarios as applicable. The scenarios noted with numerical designations (e.g., R1, R2, etc.) are those for which the Level-1 sequences-of-events have been prepared and are provided in Appendix B. The Direct Delivery class payloads cover retrieval/servicing of satellites directly reachable by the Orbiter and include nominal (MMS-type) payloads, large satellite payloads, and contamination-sensitive satellites. The LEO/Propulsion satellite class involves payload retrieval from higher energy orbits followed by rendezvous with the Orbiter for servicing. This satellite class includes consideration of integral propulsion stages (e.g., MMS-type) and

48 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY-REVISIT | | | LEO/PROPULSION - REVISIT | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROP STAGE | | VERSATILE SERV STAGE | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAM SENSITIVE PAYLOAD | NOMINAL PAYLOAD | CONTAM SENSITIVE | NOMINAL PAYLOAD | CONTAM SENSITIVE |
| • NOMINAL (RMS/TILT TABLE USAGE) | R-1 | ● | R-5 | ● | ● | R-7 | ● |
| • RMS INOPERATIVE | R-2 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 1 (RMS/HPA USAGE) | R-3 | ● | ● | ● | ● | ● | R-8 |
| • RMS INOPERATIVE | R-4 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 2 (RMS/HPA, MANNED RETRIEVAL AT 1000') | ● | ● | ● | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | | — | |
| • ALTERNATE NO. 3 (RMS/HPA, UNMANNED RETRIEVAL AT 1000') | ● | ● | R-6 | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | | — | |

IRAD

NA = NOT APPLICABLE
R-N = SCENARIOS COMPLETED

R81-0181-017(T)

Fig. 3.2-13 Revisit – Servicing Scenarios
(all scenarios include backups for hangup of mechanical devices)

Versatile Service Stage usage; for both propulsion cases, a nominal and contamination-sensitive payload are shown. Additionally, the revisit scenarios consider nominal and alternate cases, RMS-inoperative situations, and the applicable close proximity operations below:

- Direct Delivery payload class
  - Orbiter closure/satellite capture
  - "Clean" vehicle closure/satellite capture of contamination-sensitive spacecraft within 1000 ft of the Orbiter
- LEO/Propulsion payload class
  - Orbiter closure/satellite capture
  - "Clean" vehicle closure/satellite capture of contamination-sensitive spacecraft within 1000 ft of the Orbiter
  - "Clean" VSS closure where the VSS is the active vehicle closing with the Orbiter for RMS capture, after retrieving a satellite from its operational orbit.

Two additional alternate scenarios (No. 2 and 3) are also shown which utilize either manned or unmanned retrieval of satellites within 1000 ft of the Orbiter. All scenarios also include backups for hangup of mechanical devices. The R-1, R-3, and R-6 scenarios are highlighted in Fig. 3.2-13 as they will be addressed again to illustrate the techniques used to identify service equipment/usage for revisit missions. Further, the R-1 scenario, involving RMS/Tilt Table as prime service equipment, will be compared with the R-3 scenario using the RMS/HPA.

3.2.2.1 Nominal Revisit Scenarios - RMS/Tilt Table Usage

The Nominal series of scenarios referred to in the Revisit-Servicing Scenarios matrix (Ref: Fig. 3.2-13) represent scenarios where the RMS is used to retrieve satellites and place them on a Tilt Table for on-orbit servicing. Subsequent to servicing and checkout of the satellite, the RMS is used to redeploy the spacecraft from the Orbiter.

The scenarios apply to the Direct Delivery-Revisit and LEO/Propulsion-Revisit payload classes. The LEO/Propulsion class satellites, with integral stages, would return from their operational orbit to the Orbiter's nominal orbit to enable direct retrieval/capture by the Orbiter. LEO/Propulsion class satellites compatible* with the

*capable of being docked to the VSS

Versatile Service Stage (VSS) would be captured and returned from their operational orbit to the vicinity of the Orbiter, where the close proximity operations would be remotely controlled by the Orbiter crew. The VSS's "clean-burning" propulsion system would be used for these close-in operations to bring the VSS/satellite to within the RMS reach distance to effect capture. For contamination-sensitive payloads (excluding VSS-compatible satellites) a "clean-burning" Proximity Operations Module (manned or unmanned) would be deployed when the payload is within 1000 ft of the Orbiter to bring the satellite to within the RMS reach distance. As shown in the Revisit-Servicing Scenarios matrix, four Level-1 sequences-of-events were prepared (R-1, R-2, R-5, R-7) to aid in surfacing equipment utilizations.

Figure 3.2-14 shows the R-1 Level-1 revisit on-orbit sequence-of-events for the Direct Delivery-Revisit payload class, nominal payload (MMS-type), and primary RMS/FSS Cradle A' Tilt Table usage situation. Retrieval is directly accomplished by the Orbiter after examination of the satellite. Service equipment needs associated with a particular event are again highlighted, as was formerly illustrated in the sequence-of-events charts presented for initial launch. Note that the initial events call for:

- Maneuverable Television (MTV)
- Remote Manipulator System (RMS) and associated AFD Controls/Displays
- AFD Controls/Displays for close proximity flight control of the MTV.

Subsequent operations identify:

- Tilt Table (FSS Cradle A')
- OCP work platform associated with the Tilt Table
- Open Cherry Picker (OCP) and RMS
- AFD Controls/Displays for satellite checkout/servicing support
- Equipment stowage/fluid transfer system for servicing support.

The backup situations identify equipment needs:

- Manipulator Foot Restraint (MFR) to cover Tilt Table or latch hangups
- MMU/WRU with stabilizer attachment to assist a potential satellite appendage hangup.

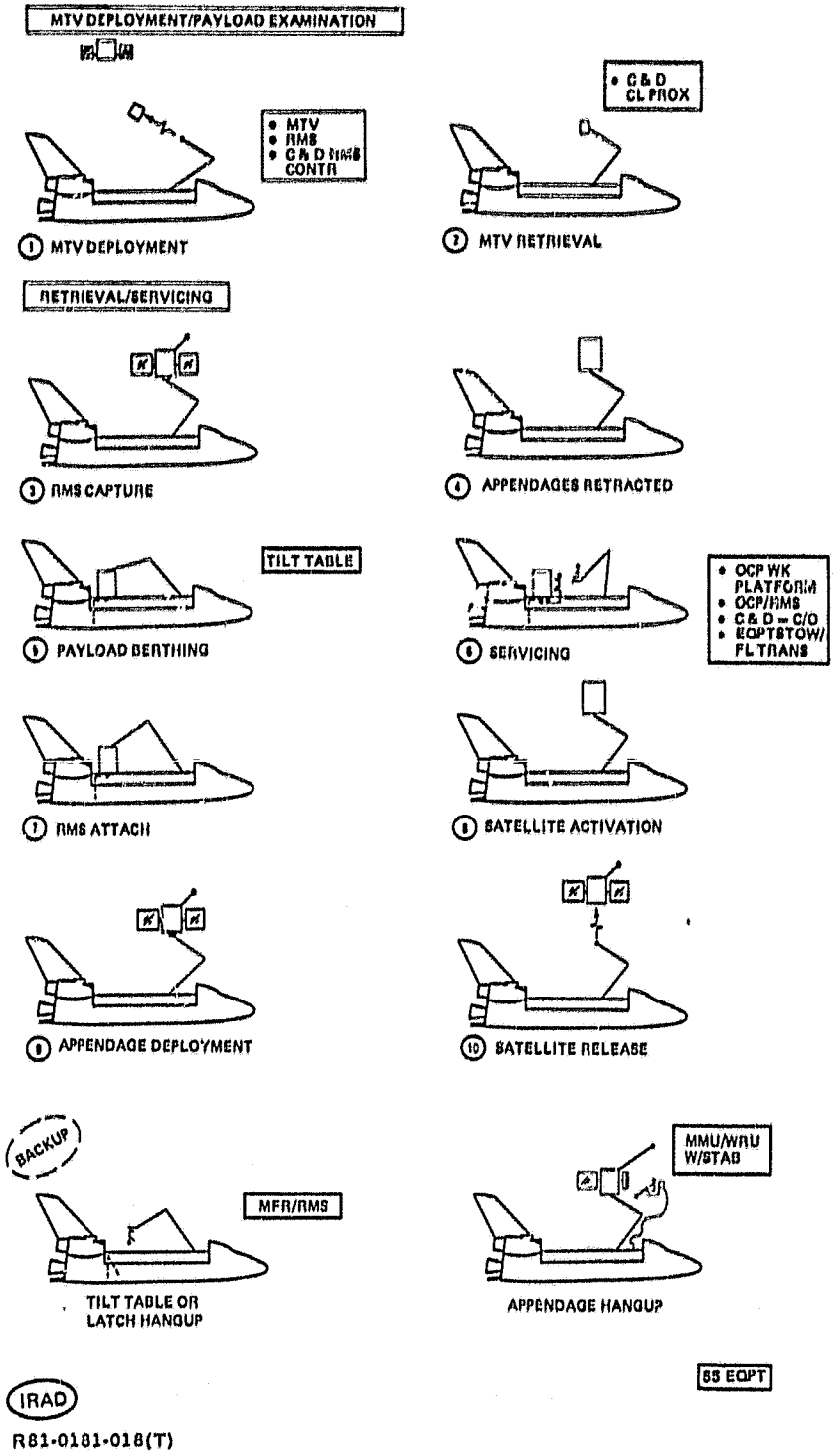



Fig. 3.2-14 R1 – Nominal Revisit Scenario – Direct Delivery Payload Class – Nominal Payload (MMS-Type) – RMS/Tilt Table Usage

The equipment usage segment of the R-1 revisit scenario, with RMS/Tilt Table prime usage, is now highlighted in Fig. 3.2-15 to illustrate the format for summarizing equipment usage for all the scenarios applicable to this nominal (RMS/Tilt Table usage) case. The equipment corresponds to that previously identified in the R-1 sequence-of-events charts. Optional equipment is also applicable, at the discretion of the satellite user.

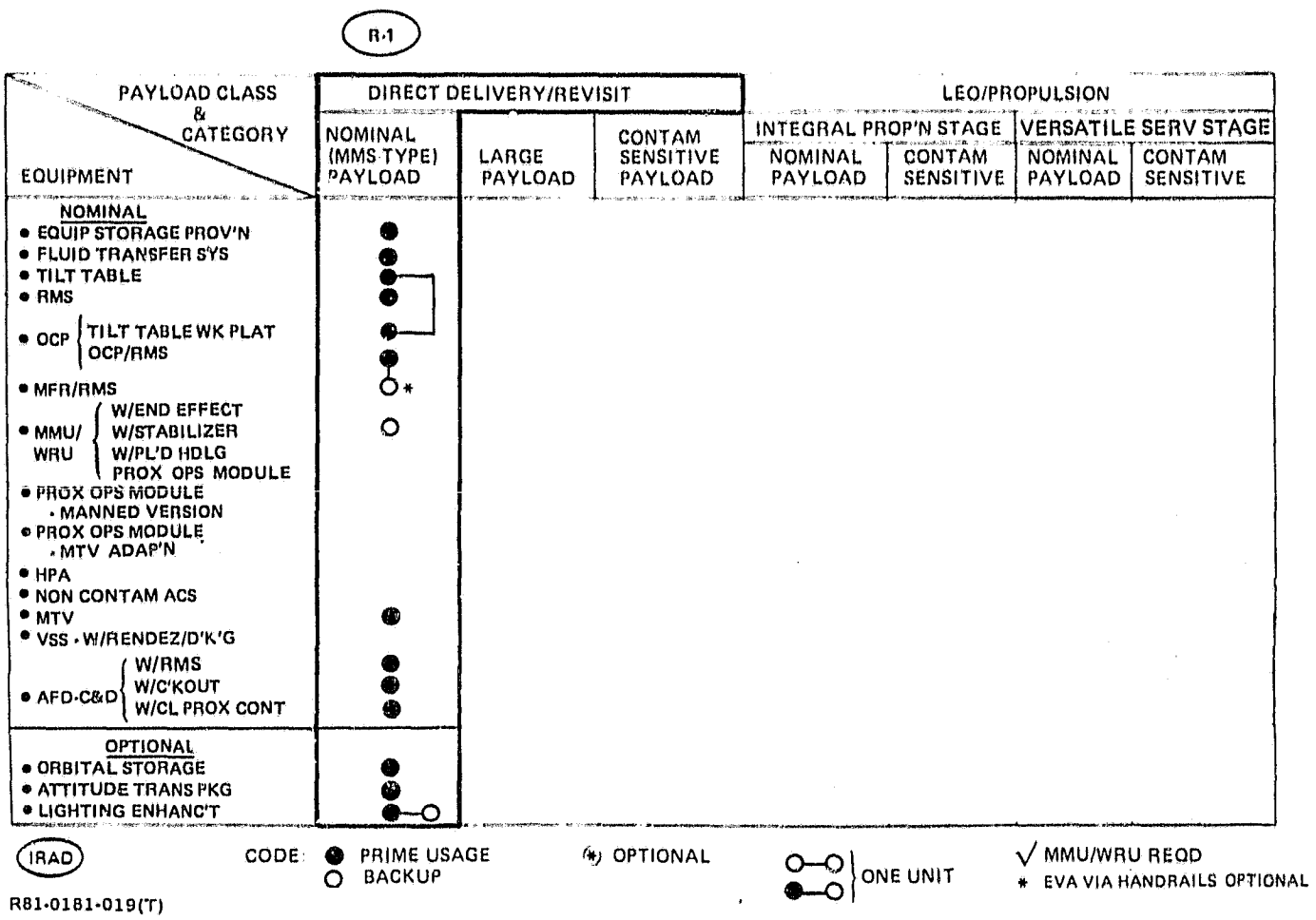



**Fig. 3.2-15 R1 — Revisit — Equipment Utilization Summary — Nominal Scenario — RMS/Tilt Table Usage**

Figure 3.2-16 is identical to Fig. 3.2-13 but now highlights the strip of seven individual scenarios applicable to this nominal RMS/Tilt Table usage situation for the various satellite classes/categories shown. Figure 3.2-17 presents the total equipment utilizations for the scenarios highlighted in the strip of scenarios in Fig. 3.2-16. Shown is the nominal, optional, and backup service equipment applicable to the seven revisit scenarios, represented by the satellite classes/categories indicated for this RMS/Tilt Table prime usage situation. Also identified are the Level-1 sequences-of-events (e.g., R-1, R-5, etc.) that were prepared to aid in surfacing the equipment identifications

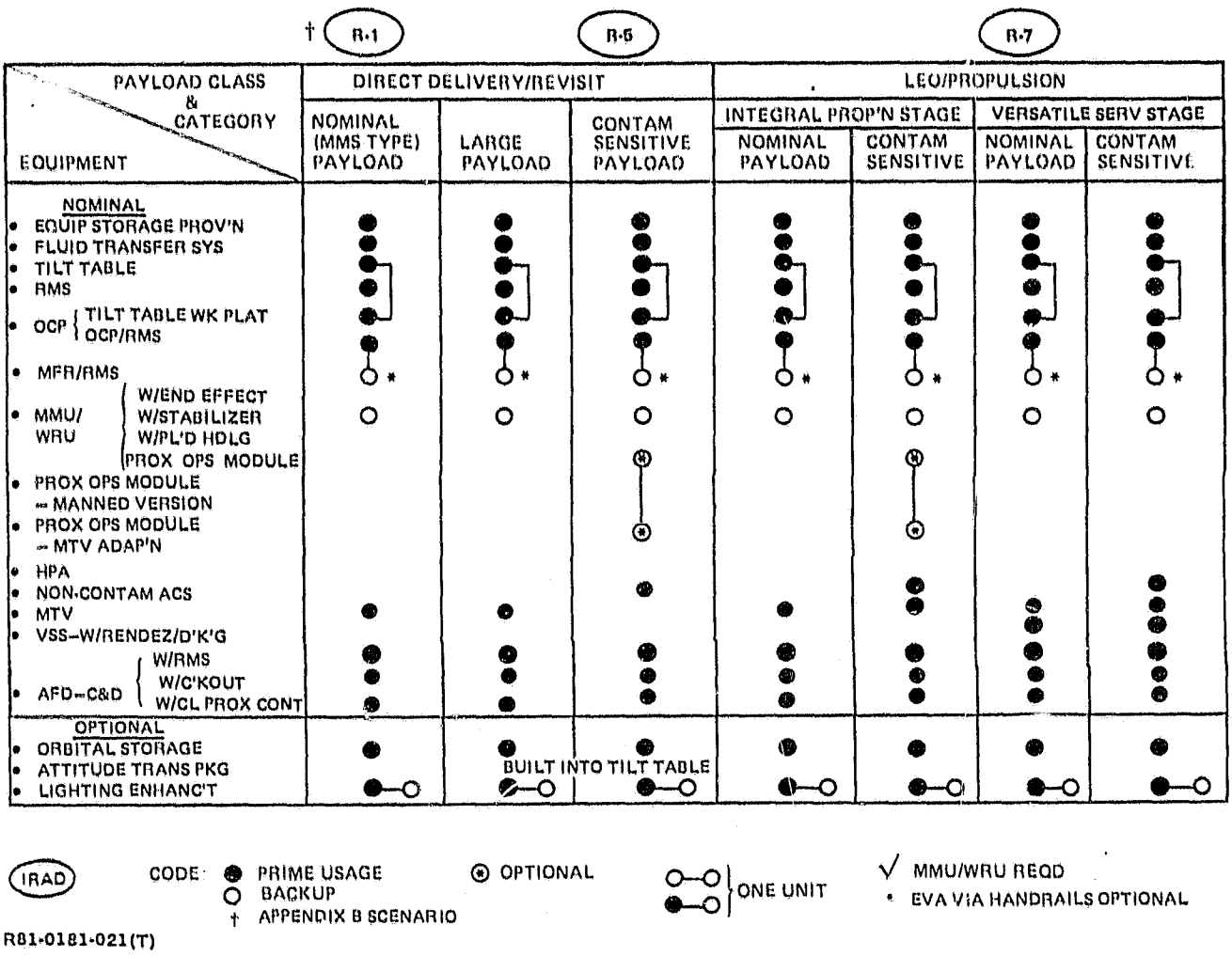
| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY/REVISIT | | | LEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROP STAGE | | VERSATILE SERV STAGE | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAM SENSITIVE PAYLOAD | NOMINAL PAYLOAD | CONTAM SENSITIVE | NOMINAL PAYLOAD | CONTAM SENSITIVE |
| • NOMINAL (RMS/TILT TABLE USAGE) | R-1 | ● | R-5 | ● | ● | R-7 | ● |
| • RMS INOPERATIVE | R-2 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 1 (RMS/HPA USAGE) | R-3 | ● | ● | ● | ● | ● | R-8 |
| • RMS INOPERATIVE | R-4 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 2 (RMS/HPA, MANNED RETRIEVAL AT 1000') | ● | ● | ● | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | | — | |
| • ALTERNATE NO. 3 (RMS/HPA, UNMANNED RETRIEVAL AT 1000') | ● | ● | R-6 | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | | — | |

IRAD

NA = NOT APPLICABLE
R-N = SCENARIOS COMPLETED

R81-0181-020(T)

**Fig. 3.2-16 Revisit — Servicing Scenarios — Nominal Scenario Emphasis — RMS/Tilt Table Usage (all scenarios include backups for hangup of mechanical devices)**




R81-0181-021(T)

**Fig. 3.2-17 Revisit — Equipment Utilization Summary — Nominal Scenario — RMS/Tilt Table Usage**

shown, which can be correlated with the scenarios found in Appendix B. Note that the equipment complements for these scenarios are essentially identical, except for the contamination-sensitive satellites wherein a "clean" propulsion form-of-retrieval and a noncontaminating Orbiter ACS are called for. Exclusive of AFD Controls/Displays and Optional Equipment, between seven and nine items of service equipment are needed to cover these revisit servicing scenarios.

Figure 3.2-18 presents the equipment complements for the same seven nominal scenarios wherein the RMS/Tilt Table is the planned prime service usage equipment (Ref.: Fig. 3.2-17), but the RMS is inoperative. The equipment complements are seen to be similar to the RMS-operative situation but now the MMU/WRU variations are necessary to complete the missions. Note, however, that a second MMU/WRU with stabilizer is also needed for these seven scenarios. Exclusive of AFD Controls/Displays and optional

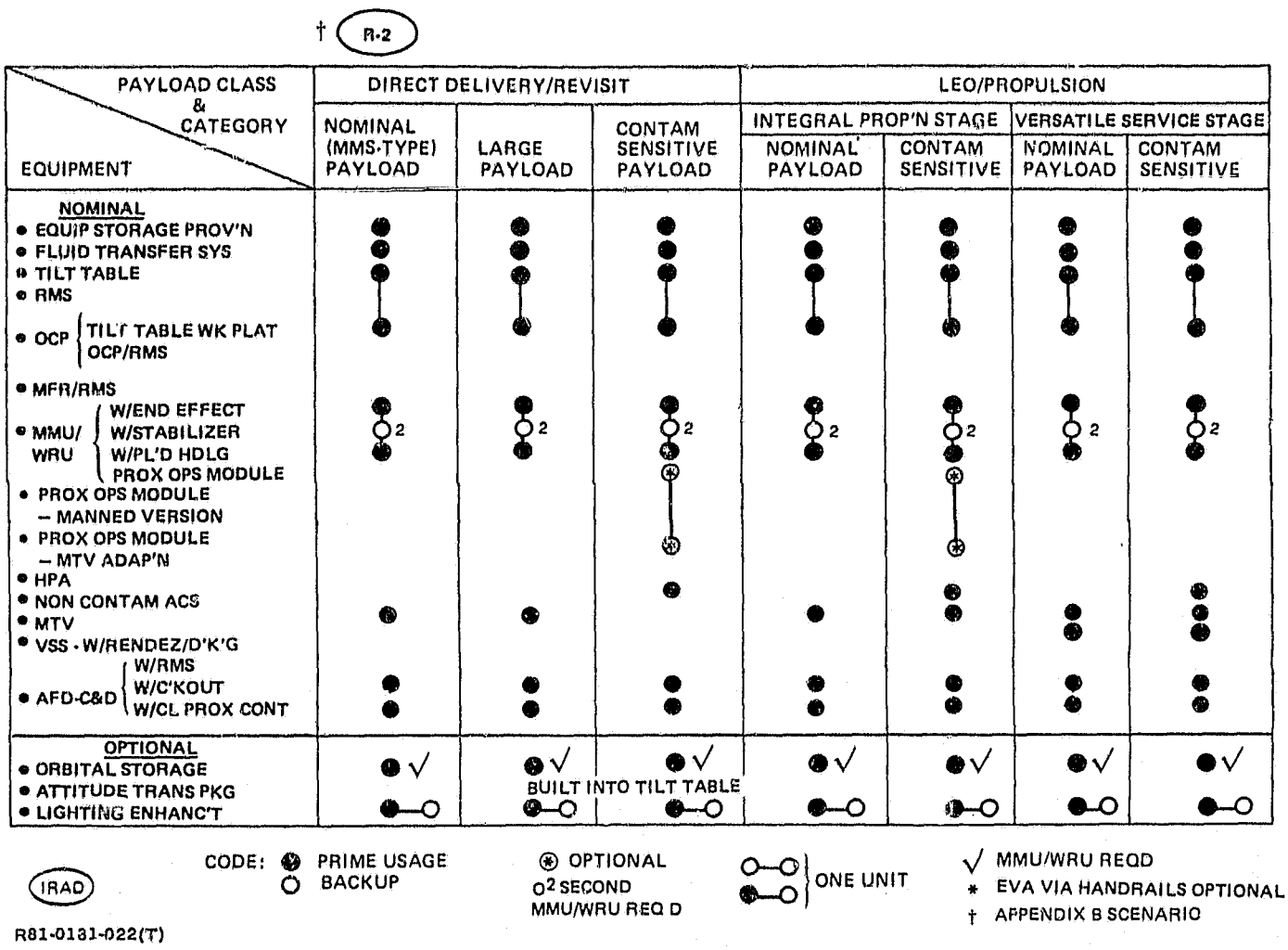



**Fig. 3.2-18 Revisit – Equipment Utilization Summary – Nominal Scenario – RMS/Tilt Table Usage – RMS Inoperative**

equipment, between six and eight items of service equipment are needed to cover these revisit servicing scenarios.

3.2.2.2 Alternate Revisit Scenarios No. 1 - RMS/HPA Usage

The Alternate No. 1 series of scenarios referred to in the Revisit-Servicing Scenarios matrix (Ref: Fig. 3.2-13) represents scenarios where the RMS is used to retrieve satellites and place them on a Handling/Positioning Aid (HPA) for on-orbit servicing. In these scenarios, the HPA becomes the "standard location" at which servicing and checkout of the satellite is performed, and from which the spacecraft is redeployed from the Orbiter.

The Alternate No. 1 scenarios apply to the Direct Delivery-Revisit and LEO/Propulsion-Revisit payload classes. The close proximity and retrieval operations associated with the payload classes/categories are the same as with the Nominal Revisit Scenarios (Sec. 3.2.2.1). As shown in the Revisit-Servicing Scenarios matrix, three Level-1 sequences-of-events were prepared (R-3, R-4, R-8) to aid in surfacing equipment utilizations.

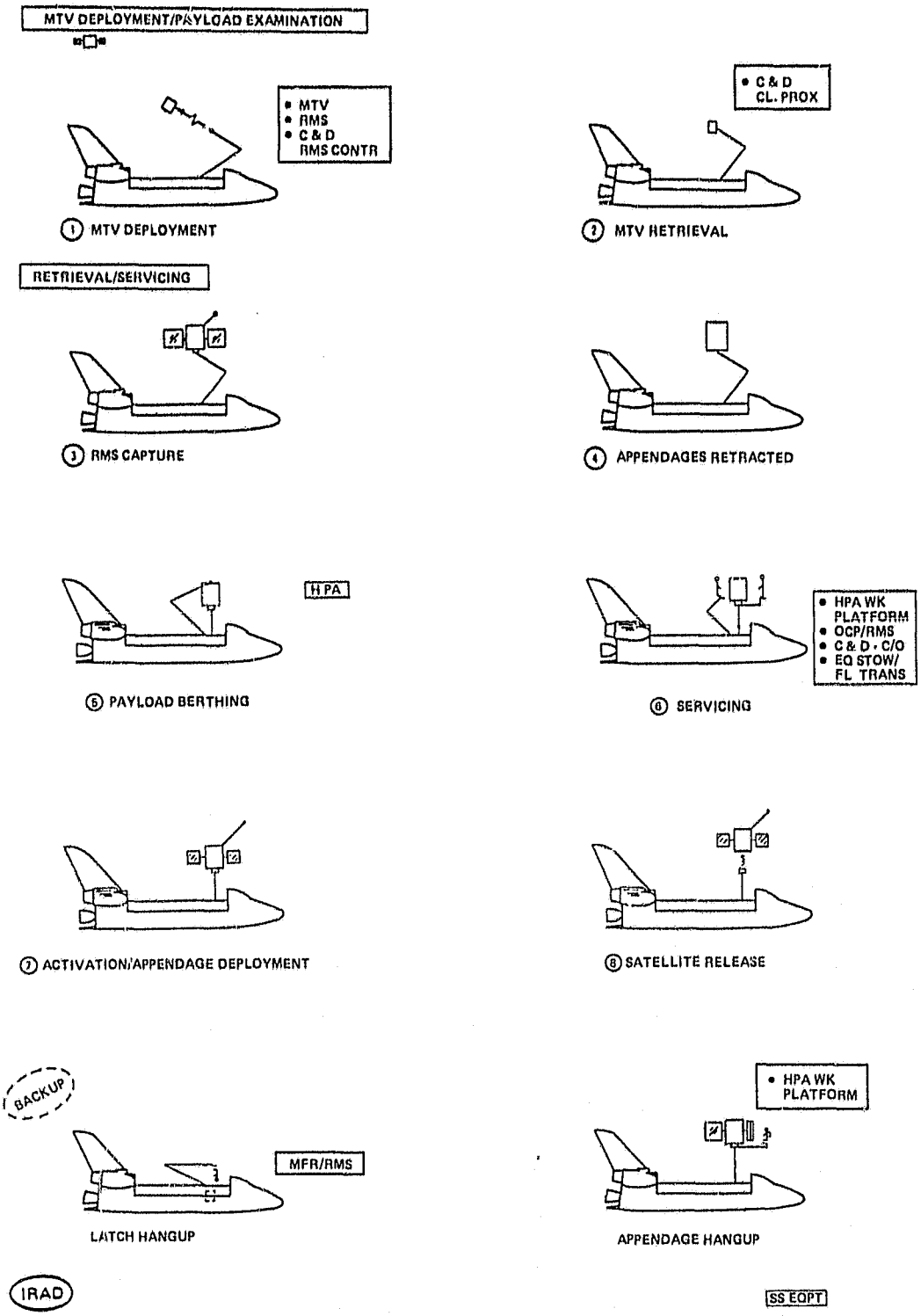
Figure 3.2-19 shows the R-3 Level-1 revisit on-orbit sequence-of-events for the Direct Delivery-Revisit payload class, nominal payload (MMS-type). Retrieval is again directly accomplished by the Orbiter after inspection of the satellite. Service equipment needs associated with a particular event are again highlighted, as was formerly illustrated for other sequence-of-events charts. The initial events call for:

- Maneuverable Television (MTV)
- Remote Manipulator System (RMS) and associated AFD Controls/Displays
- AFD Controls/Displays for close proximity flight control of the MTV.

Subsequent operations identify:

- Handling and Positioning Aid (HPA)
- Work Platform for the HPA
- Open Cherry Picker (OCP) and RMS
- AFD Controls/Displays for satellite checkout/servicing support
- Equipment stowage/fluid transfer systems for servicing support.

The backup situations identify the following equipment needs:

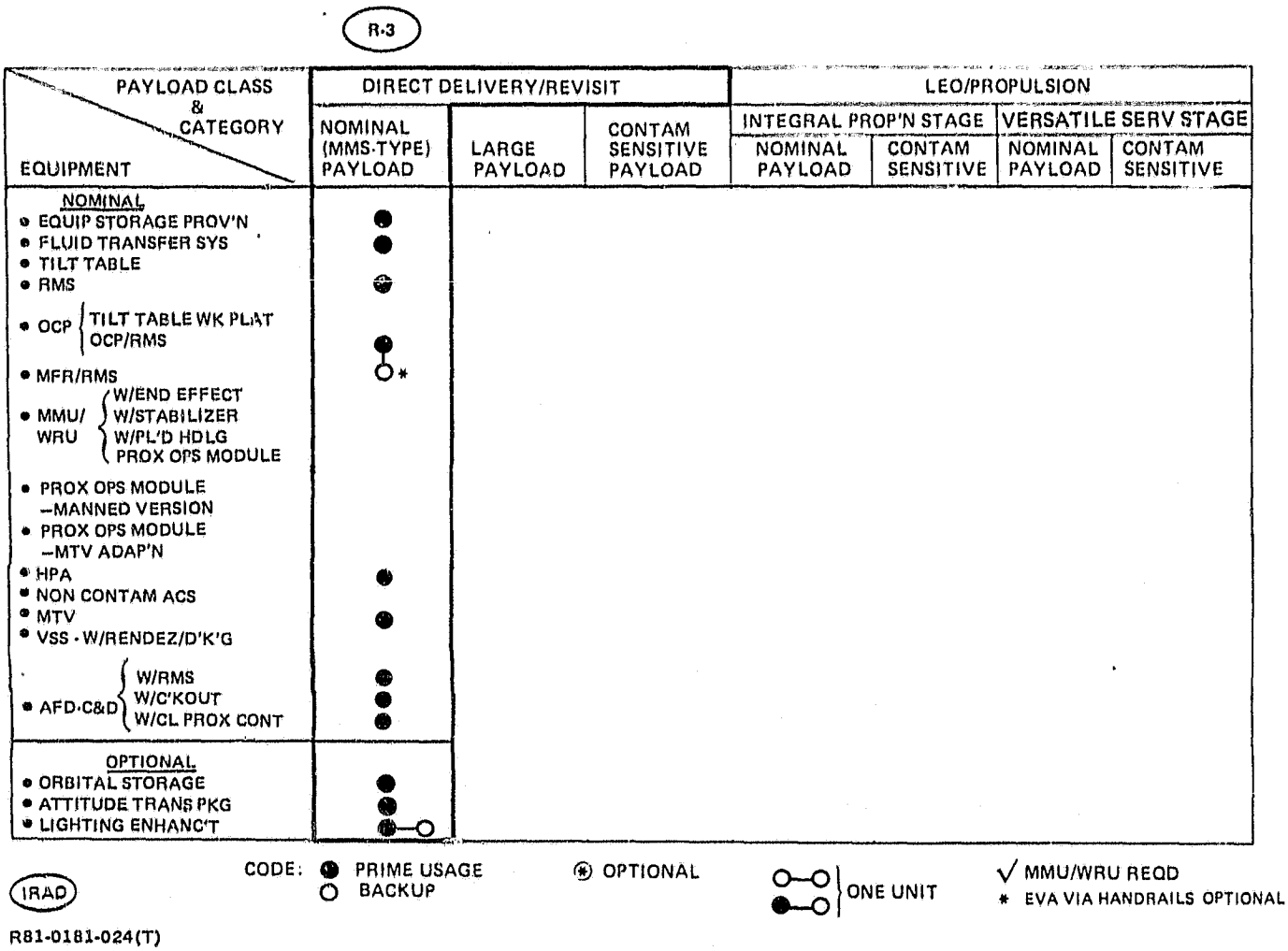



R81-0181-023(T)

**Fig. 3.2-19 R 3 – Alternate No. 1 Revisit Scenario – Direct Delivery Payload Class – Nominal Payload (MMS – Class) – RMS/HPA Usage**

- Manipulator Foot Restraint (MFR) to cover latch hangups
- HPA work platform (also identified above) to assist a potential satellite appendage hangup.

The equipment usage for the R-3 revisit scenario, with RMS/HPA prime usage, is highlighted in Fig. 3.2-20, within the overall format being used to identify equipment usage for all the scenarios applicable to this Alternate No. 1 (RMS/HPA usage) case. The equipment corresponds to that identified in the R-3 sequence-of-events chart shown previously, and also includes the optional equipment applicable for this scenario.




R81-0181-024(T)

Fig. 3.2-20 R3 – Revisit – Equipment Utilization Summary – Alternate Scenario No. 1 – RMS/HPA Usage

Figure 3.2-21 again repeats the original Revisit-Servicing Scenarios matrix (Ref: Fig. 3.2-12), but highlights the strip of seven individual scenarios applicable to this RMS/HPA usage situation for the various satellite classes/categories shown. Figure 3.2-22 summarizes the equipment utilizations for the scenarios emphasized in Fig. 3.2-21. Shown is the nominal, optional, and backup service equipment applicable to the seven revisit scenarios represented by the satellite classes/categories indicated for this RMS/HPA prime usage situation. Also identified are the Level-1 sequences-of-events (R-3, R-8) that were prepared to aid in surfacing the equipment identifications shown and can be correlated with the scenarios found in Appendix B. The equipment complements for these scenarios are essentially identical, except for the contamination-sensitive satellites wherein a "clean" propulsion form-of-retrieval and a noncontaminating Orbiter ACS are called for. Exclusive of AFD Controls/Displays and optional

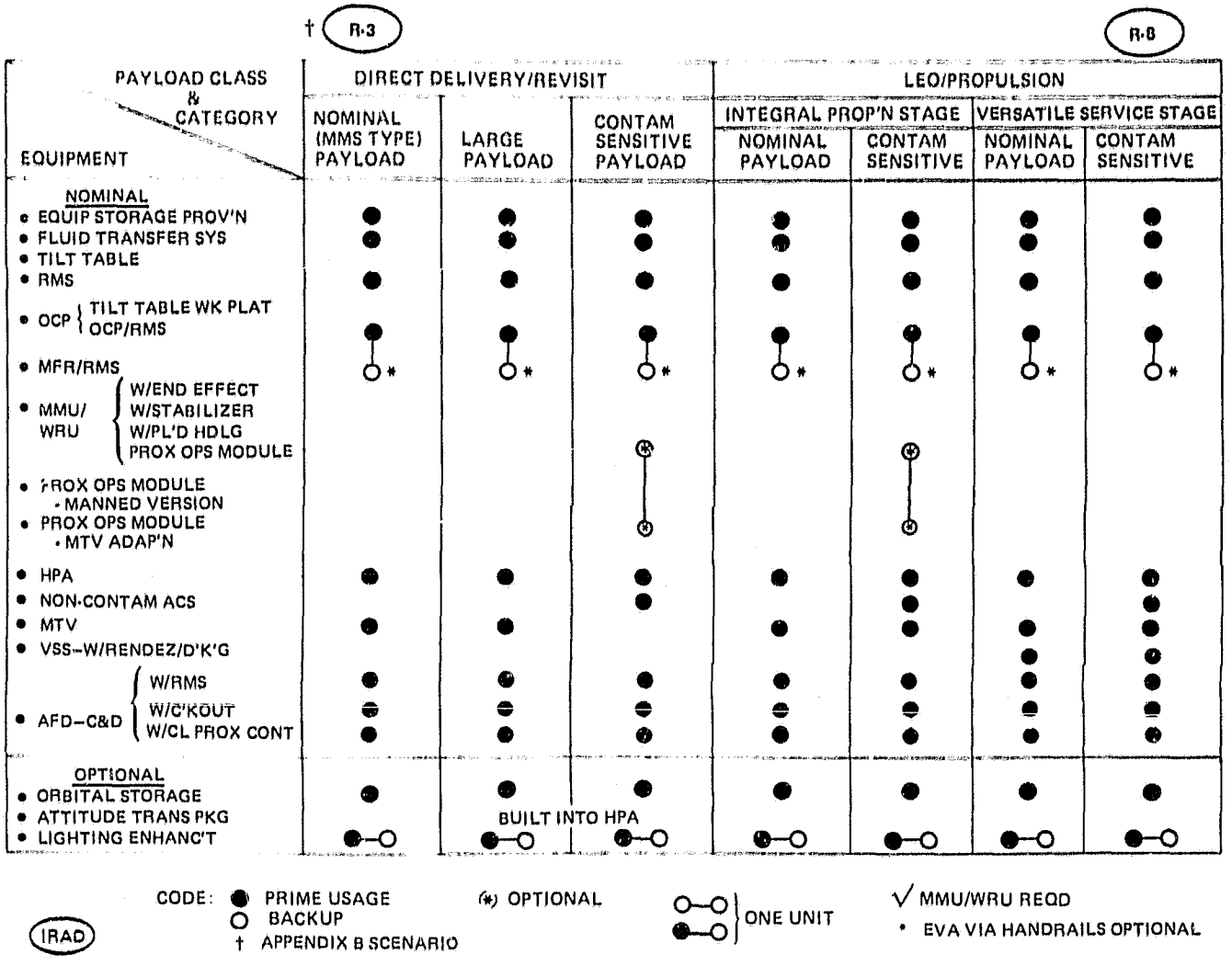
| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY/REVISIT | | | LEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROP STAGE | | VERSATILE SERV STAGE | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAM SENSITIVE PAYLOAD | NOMINAL PAYLOAD | CONTAM SENSITIVE | NOMINAL PAYLOAD | CONTAM SENSITIVE |
| • NOMINAL (RMS/TILT TABLE USAGE) | R-1 | ● | R-5 | ● | ● | R-7 | ● |
| • RMS INOPERATIVE | R-2 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 1 (RMS/HPA USAGE) | R-3 | ● | ● | ● | ● | ● | R-8 |
| • RMS INOPERATIVE | R-4 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 2 (RMS/HPA, MANNED RETRIEVAL AT 1000') | ● | ● | ● | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | | — | |
| • ALTERNATE NO. 3 (RMS/HPA, UNMANNED RETRIEVAL AT 1000') | ● | ● | R-6 | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | | — | |

IRAD

NA = NOT APPLICABLE
R-N = SCENARIOS COMPLETED

R81-0181-025(T)

Fig. 3.2-21 Revisit — Servicing Scenarios — Alternate Scenario No. 1 Emphasis — RMS/HPA Usage (all scenarios include backups for hangup of mechanical devices)



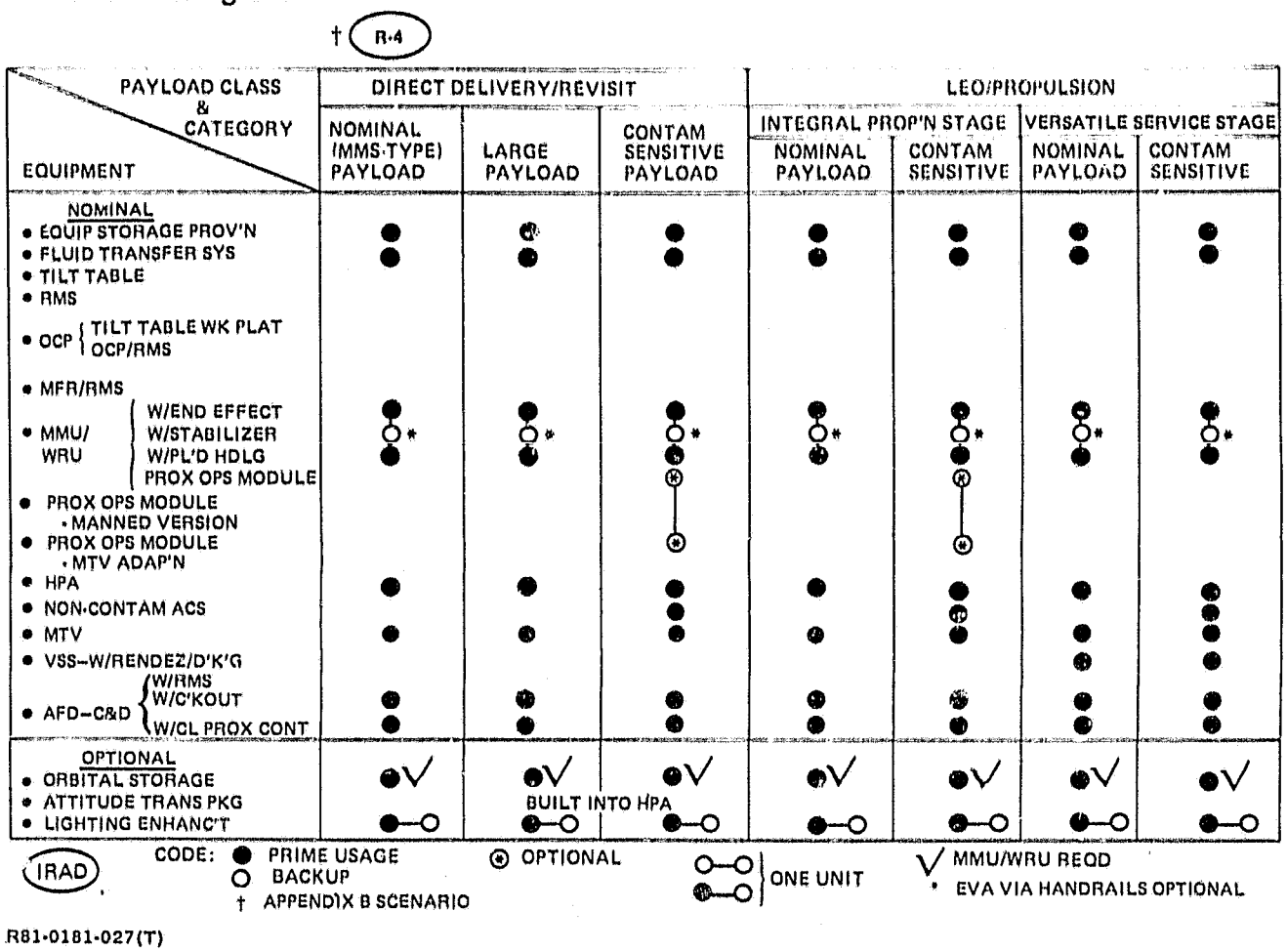

R81-0181-026(T)

**Fig. 3.2-22 Revisit — Equipment Utilization Summary — Alternate Scenario No.1 — RMS/HPA Usage**

equipment, between six and eight items of service equipment are needed to cover these revisit service scenarios.

A comparison of the equipment utilization summaries between RMS/Tilt Table usage (Fig. 3.2-17) and RMS/HPA usage (Fig. 3.2-22) shows that one less item of service equipment (MMU/WRU with stabilizer) is needed for the service scenarios utilizing the HPA.

The equipment complements for the RMS-inoperative situation relating to the seven (Alternate No. 1) scenarios, where the RMS/HPA is the planned prime service usage equipment, are shown in Fig. 3.2-23. The equipment complements are similar to the RMS-operative situation (Ref: Fig. 3.2-22), but now the MMU/WRU variations are again necessary to complete the missions. Exclusive of AFD Controls/Displays and optional equipment, between five and seven items of service equipment are needed to cover these revisit servicing scenarios.




R81-0181-027(T)

**Fig. 3.2-23 Revisit — Equipment Utilization Summary — Alternate Scenario No. 1 — RMS/HPA Usage — RMS Inoperative**

Comparing the RMS/Tilt Table (Fig. 3.2-18) vs. RMS/HPA (Fig. 3.2-23) usage scenarios with RMS-inoperative, we again find that one less item of service equipment (MMU/WRU with stabilizer) is needed for the service scenarios utilizing the HPA.

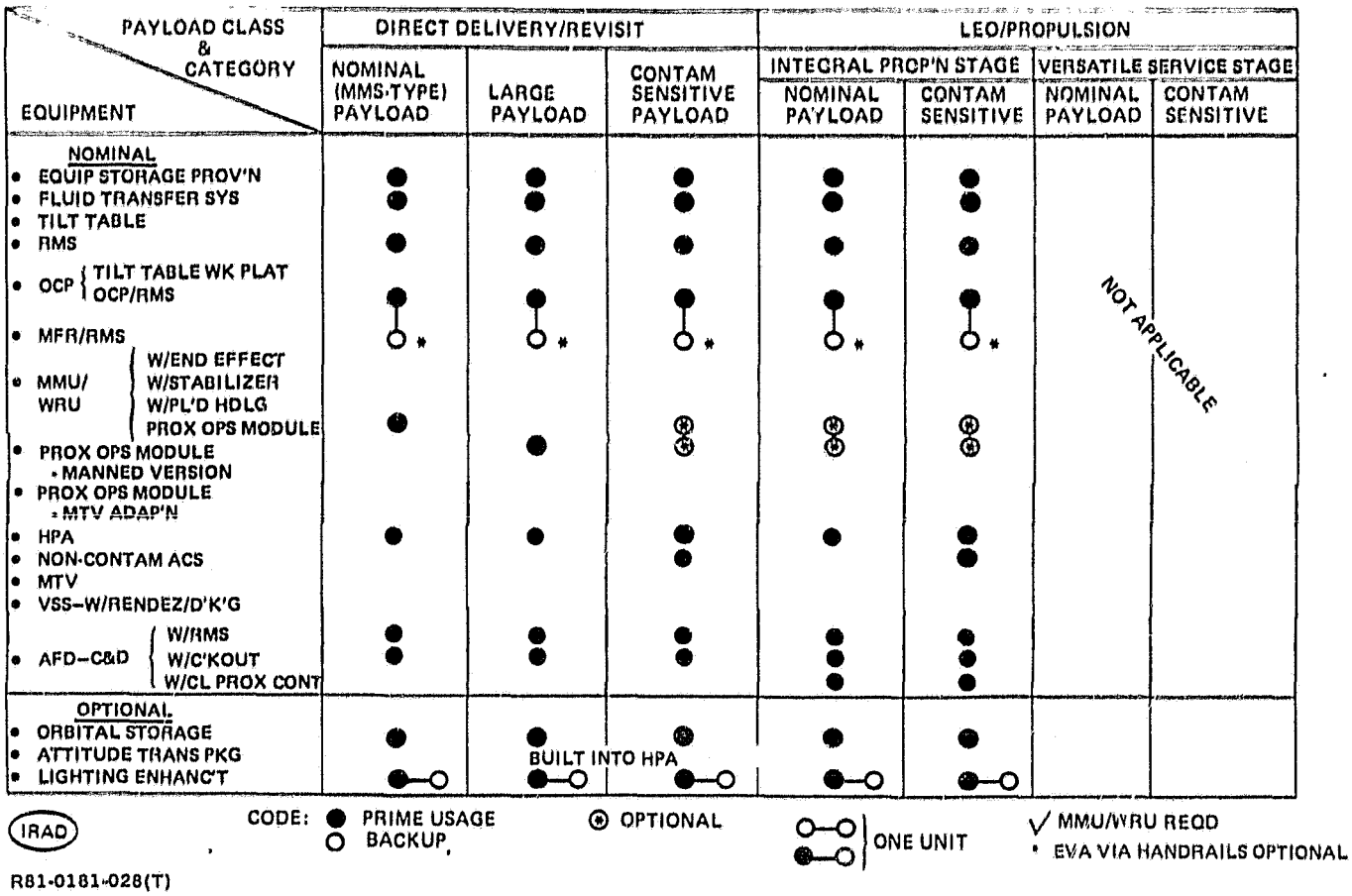
### 3.2.2.3 Alternate Revisit Scenarios No. 2 - RMS/HPA Usage - Manned Retrieval at 1000 ft Separation

The Alternate No. 2 series of scenarios referred to in the Revisit-Servicing Scenarios matrix (Ref: Fig. 3.2-13) represent scenarios in which the Orbiter would rendezvous within 1000 ft of a payload, and a manned Proximity Operations Module (POM) is dispatched to retrieve and bring the payload to within RMS reach distance. The payload is then captured by the RMS and placed on the Handling/Positioning Aid for on-orbit servicing. Following servicing and checkout, the spacecraft is redeployed from the Orbiter.

The scenarios apply to the Direct Delivery-Revisit payload class and the LEO/Propulsion-Revisit payload class with an integral propulsion stage. The satellite, with its integral stage, would return from its operational orbit to the Orbiter's nominal orbit to enable capture of the satellite/stage by the POM and retrieval by the RMS/Orbiter.

The equipment usage for the Alternate No. 2 revisit scenarios is shown in Fig. 3.2-24. The nominal, optional, and backup service equipment is shown for the five revisit scenarios in which manned retrieval of satellites at 1000 ft separation is applicable. Manned retrievals can be accomplished by Proximity Operations Modules (POM) in either of two variations: an "MMU/WRU adaptation" or a "Manned Version." The distinction between the two is that the POM-MMU/WRU adaptation applies to masses in the range of MMS-type payloads (or smaller); for larger payloads (such as AXAF), a larger POM-Manned Version has been called for.

As shown in Fig. 3.2-24, the service equipment complements for these scenarios are similar, except for the contamination-sensitive payloads which call for a noncontaminating Orbiter ACS during on-orbit servicing. Exclusive of AFD Controls/Displays and optional equipment, six or seven items of service equipment are needed to cover these revisit service scenarios.




R81-0181-028(T)

Fig.3.2-24 Revisit – Equipment Utilization Summary – Alternate Scenario No. 2 – RMS/HPA Usage – Manned Retrieval of Satellites at 1000 Ft Separation

Figure 3.2-25 presents the equipment complements for the same five Alternate No. 2 scenarios reflected in Fig. 3.2-24, but now with the RMS-inoperative. Once again, MMU/WRU adaptations appear as the contingency elements for RMS-inoperative situations. Note, however, that in this HPA usage situation a single MMU/WRU is needed, as contrasted with the Tilt Table usage case (Fig. 3.2-18) where two MMU/WRUs are called for. Exclusive of AFD Controls/Displays and optional equipment, five or six items of service equipment are needed to cover these revisit service scenarios.

Of interest is that one less item of service equipment is needed for this RMS-inoperative case than was called for in the RMS-operative situation. The MMU/WRU adaptations (e.g., with end-effector, with stabilizer, and with payload handling capability) built within a single, modularly-adaptable WRU could replace the RMS and OCP/MFR functions.

### 3.2.2.4 Alternate Revisit Scenarios No. 3 - RMS/HPA Usage - Unmanned Retrieval at 1000 ft Separation

The Alternate No. 3 series of scenarios referred to in the Revisit-Servicing Scenarios matrix (Ref: Fig. 3.2-13) represent scenarios where the Orbiter would rendezvous within 1000 ft of a payload. An unmanned Proximity Operations Module (POM) is then dispatched to retrieve and bring the payload within RMS reach distance where it is captured by the RMS and placed on the Handling/Positioning Aid for on-orbit servicing. Following servicing and checkout, the spacecraft is redeployed from the Orbiter.

The scenarios apply to the Direct Delivery-Revisit payload class and the LEO/Propulsion-Revisit payload class with an integral propulsion stage. The satellite, with its integral stage, would return from its operational orbit to the Orbiter's nominal orbit to enable capture of the satellite/stage by the POM and retrieval by the RMS/Orbiter. As shown in the Revisit-Servicing Scenarios matrix, the R-6 Level-1 sequence-of-events was prepared to aid in surfacing equipment utilizations.

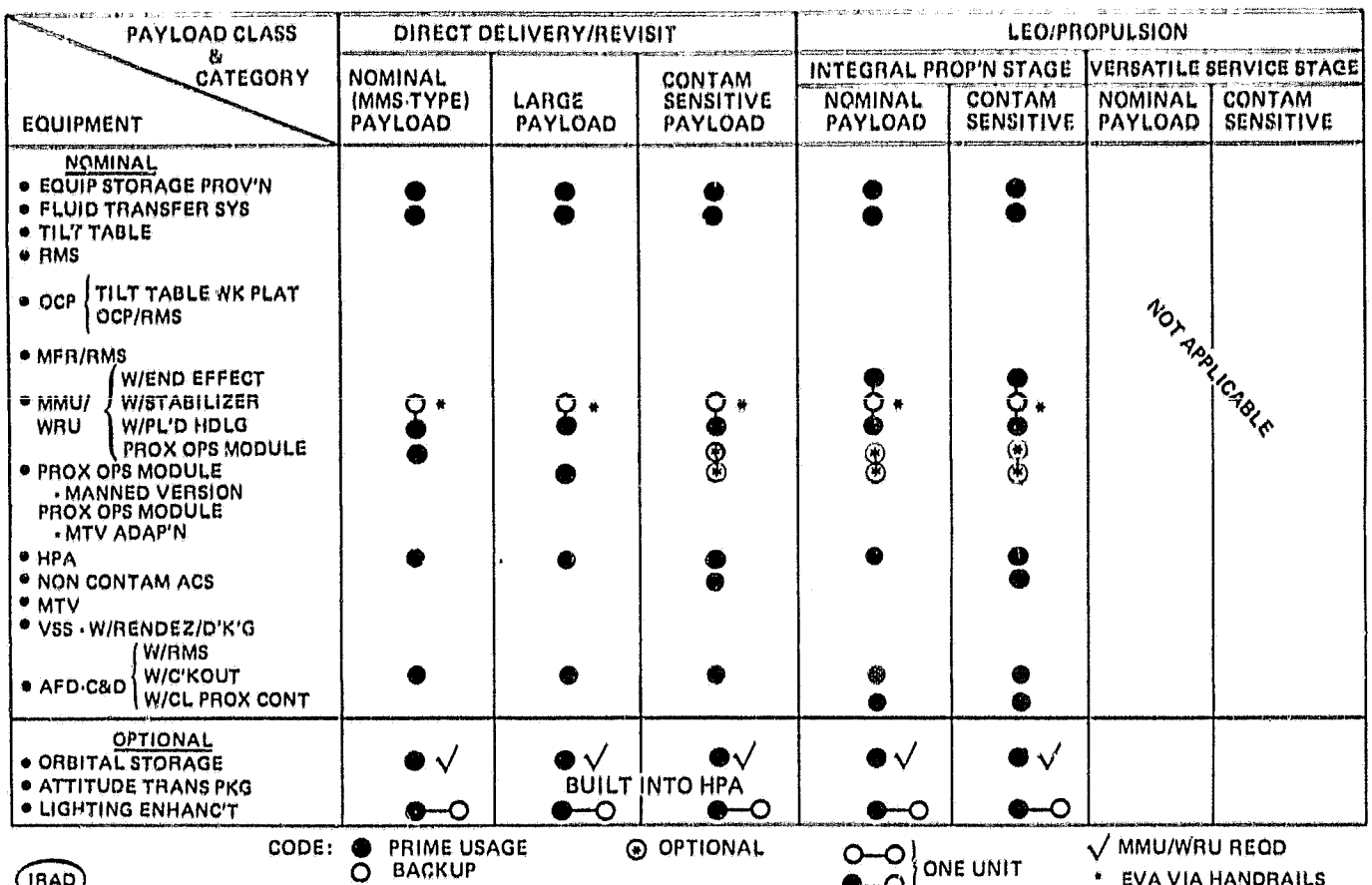



Fig. 3.2-25 Revisit — Equipment Utilization Summary — Alternate Scenario No. 2 — RMS/HPA Usage — Manned Retrieval of Satellites at 1000 Ft Separation — RMS Inoperative

Figure 3.2-26 shows the R-6 Level-1 revisit on-orbit sequence-of-events for the Direct Delivery-Revisit payload class, contamination-sensitive satellite. Service equipment needs are again highlighted as they appear in the scenario and for backup situations. The initial events call for:

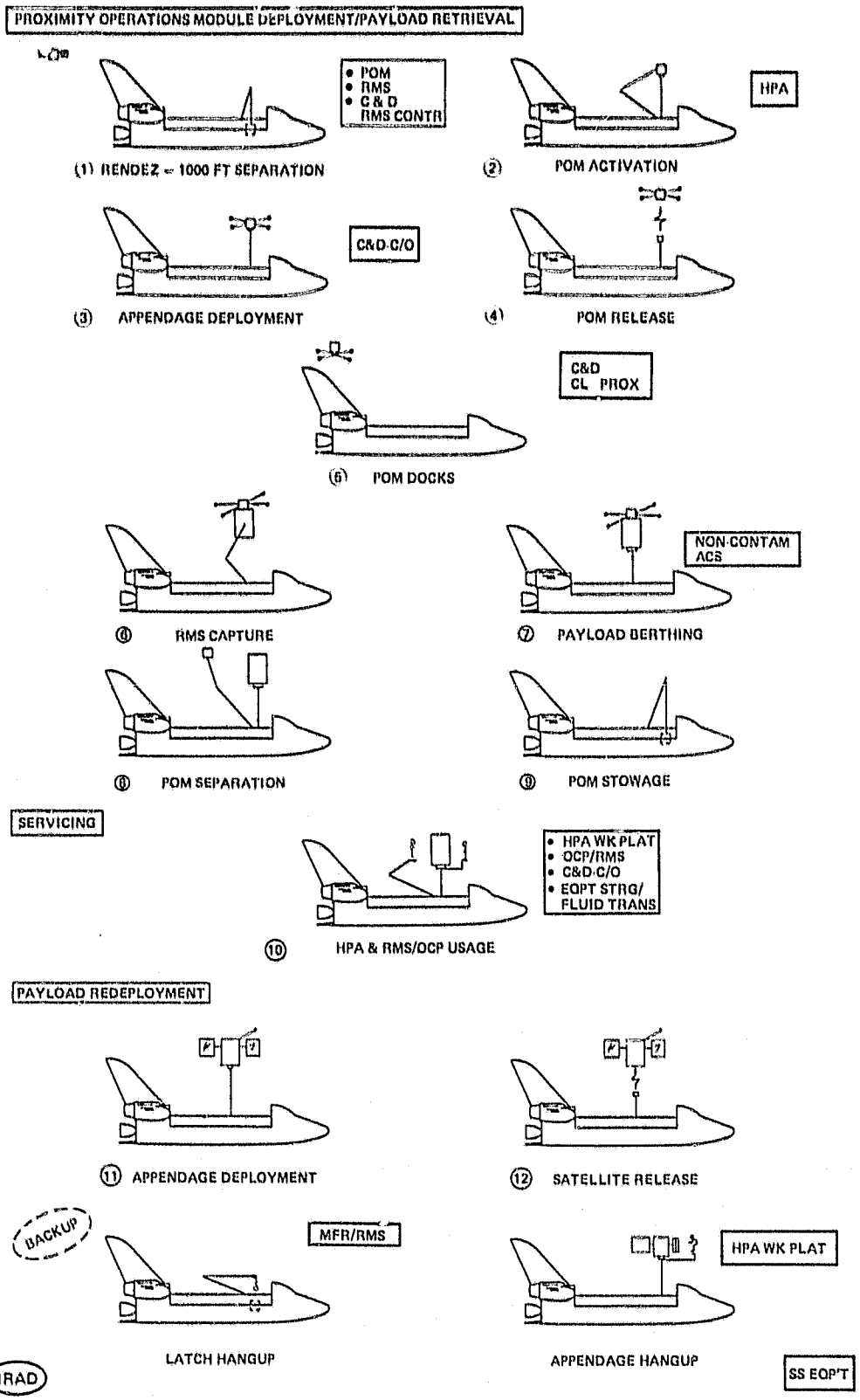
- Proximity Operations Module (POM) which can be an adaptation of the Maneuverable Television (MTV)
- Remote Manipulator System (RMS) and associated AFD Controls/Displays
- Handling and Positioning Aid (HPA)
- AFD Controls/Displays for checkout of the POM
- AFD Controls/Displays for close proximity flight control of the POM.

Subsequent operations identify:

- Noncontaminating Orbiter ACS to enable servicing of the contamination-sensitive satellite
- Work Platform for the HPA
- Open Cherry Picker (OCP) and RMS
- AFD Controls/Displays for satellite checkout/servicing support
- Equipment storage/fluid transfer for servicing support.

Backup situations identify the following equipment needs:

- Manipulator Foot Restraint (MFR) to cover latch hangups
- HPA work platform (also identified above) to assist a potential satellite appendage hangup.




R81-0181-030(T)

Fig. 3.2-26 R6 – Alternate No. 3 Revisit Scenario – Direct Delivery Payload Class – Contamination Sensitive Satellite – RMS/HPA Usage – Unmanned Retrieval at 1000 Ft Separation

The equipment usage segment of the R-6 scenario is shown highlighted in Fig. 3.2-27, within the overall format being used to identify equipment usage for all the scenarios applicable to this Alternate No. 3 case. The primary/backup equipment shown corresponds with that appearing on the previous Level-1 sequence-of-events charts. Optional service equipment that are applicable are also shown.

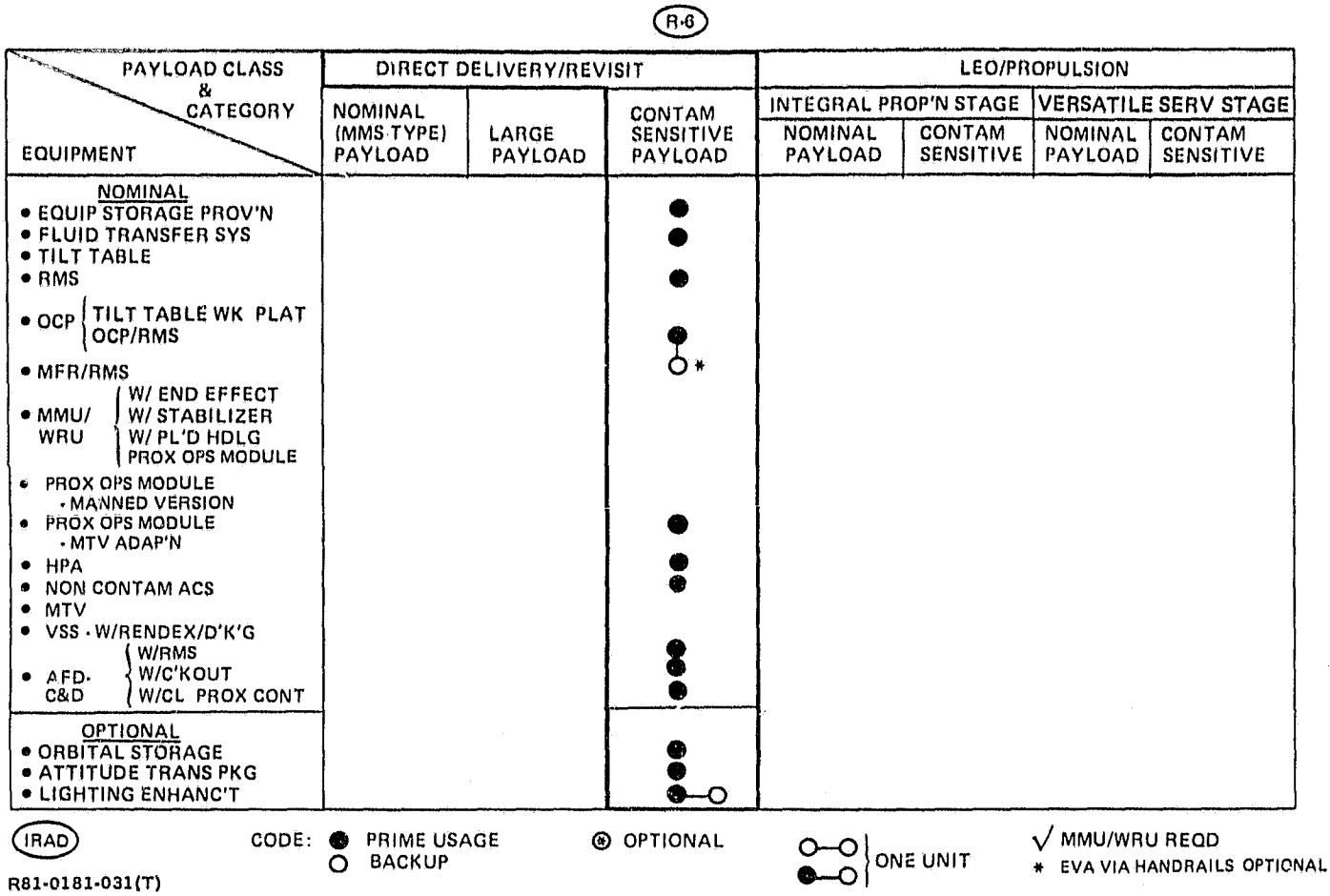



**Fig. 3.2-27 R6 — Revisit — Equipment Utilization Summary — Alternate Scenario No. 3 — RMS/HPA Usage — Unmanned Retrieval of Satellites at 1000 Ft Separation**

Figure 3.2-28 repeats the original Revisit-Servicing Scenarios matrix (Ref: Fig. 3.2-13), but highlights the strip of five scenarios applicable to this RMS/HPA usage situation, coupled with unmanned retrieval of satellites within a 1000 ft Orbiter separation distance. The next illustration (Fig. 3.2-39) summarizes the equipment utilizations for the scenarios emphasized in Fig. 3.2-28.

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY/REVISIT | | | LEO/PROPULSION | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROP STAGE | | VERSATILE SERV STAGE | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAM SENSITIVE PAYLOAD | NOMINAL PAYLOAD | CONTAM SENSITIVE | NOMINAL PAYLOAD | CONTAM SENSITIVE |
| • NOMINAL (RMS/TILT TABLE USAGE) | R-1 | ● | R-5 | ● | ● | R-7 | ● |
| • RMS INOPERATIVE | R-2 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 1 (RMS/HPA USAGE) | R-3 | ● | ● | ● | ● | ● | R-8 |
| • RMS INOPERATIVE | R-4 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 2 (RMS/HPA, MANNED RETRIEVAL AT 1000') | ● | ● | ● | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | | — | |
| • ALTERNATE NO. 3 (RMS/HPA, UNMANNED RETRIEVAL AT 1000') | ● | ● | R-6 | ● | ● | NA | |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | NA | |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | | — | |

NA = NOT APPLICABLE
R-N = SCENARIOS COMPLETED

IRAD

R81-0181-032(T)

**Fig. 3.2-28 Revisit — Servicing Scenarios — Alternate Scenario No. 3 Emphasis — RMS/HPA Usage — Unmanned Retrieval at 1000 Ft Separation (all scenarios include backups for hangup of mechanical devices)**

Figure 3.2-29 identifies the nominal, optional, and backup service equipment for these five revisit scenarios. Retrievals are accomplished by a Proximity Operations Module-MTV adaptation capable of handling the spectrum of satellite masses projected in our Satellite and Services User Model (S/SUM). Service equipment complements are almost identical to the manned retrieval scenarios (Fig. 3.2-25), but with the addition of an Aft Flight Deck Control/Display for close proximity flight control (remote) of the POM by the Orbiter crew. Exclusive of AFD Controls/Displays and optional equipment, six or seven items of service equipment are needed to cover these revisit-servicing scenarios.

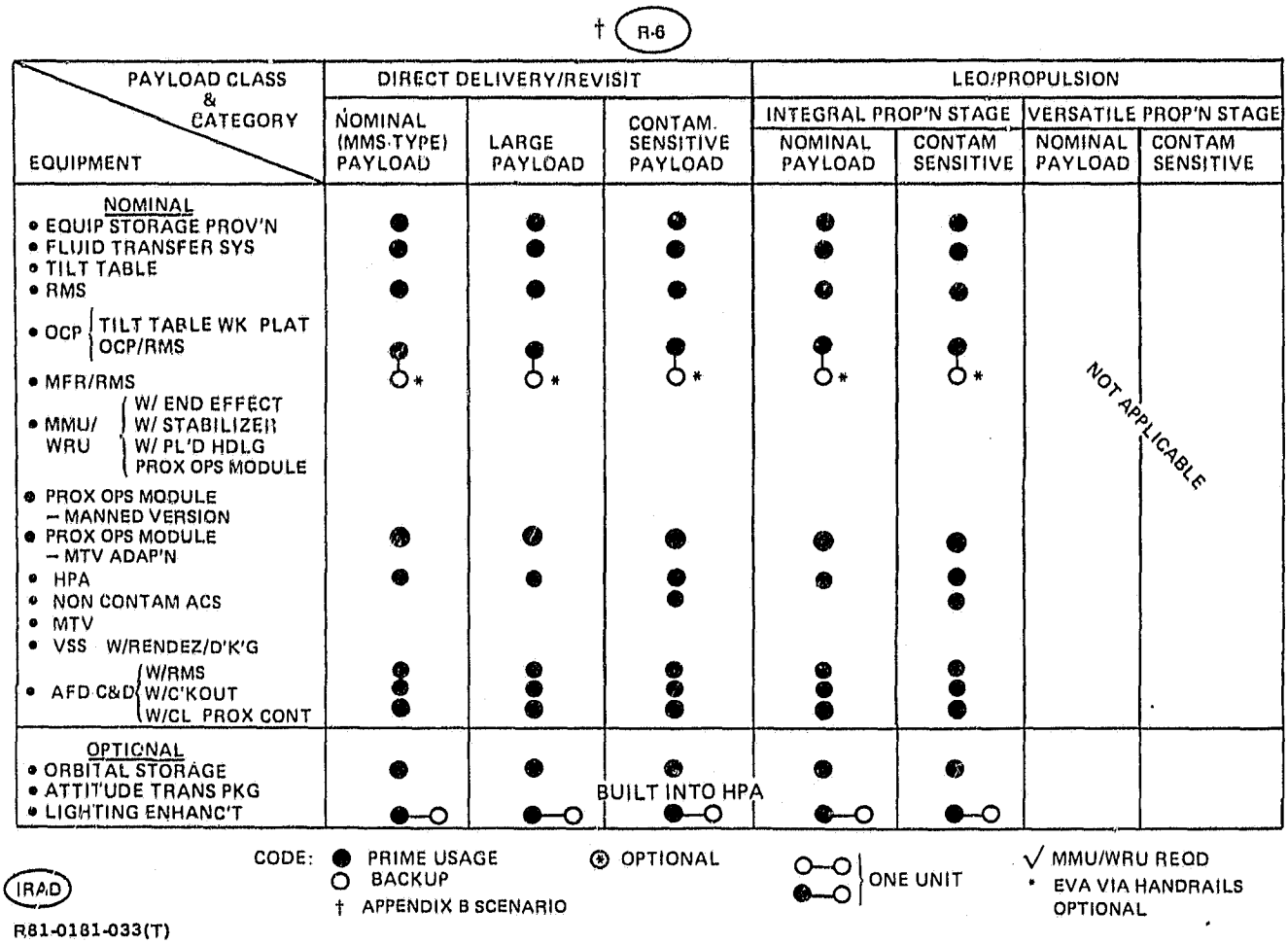



**Fig. 3.2-29 Revisit – Equipment Utilization Summary – Alternate Scenario No. 3 – RMS/HPA Usage – Unmanned Retrieval of Satellites at 1000 Ft Separation**

Figure 3.2-30 presents the equipment needs for the same five Alternate No. 2 scenarios reflected in Fig. 3.2-29, but now with the RMS inoperative. Again, the MMU/WRU adaptations appear as the contingency elements for RMS-inoperative situations. Exclusive of AFD Controls/Displays and optional equipment, five or six items of service equipment are needed to cover these revisit servicing scenarios. As was noted for the manned retrieval situation with RMS inoperative, this unmanned retrieval situation also calls for one less item of service equipment than in the RMS-operative situation.

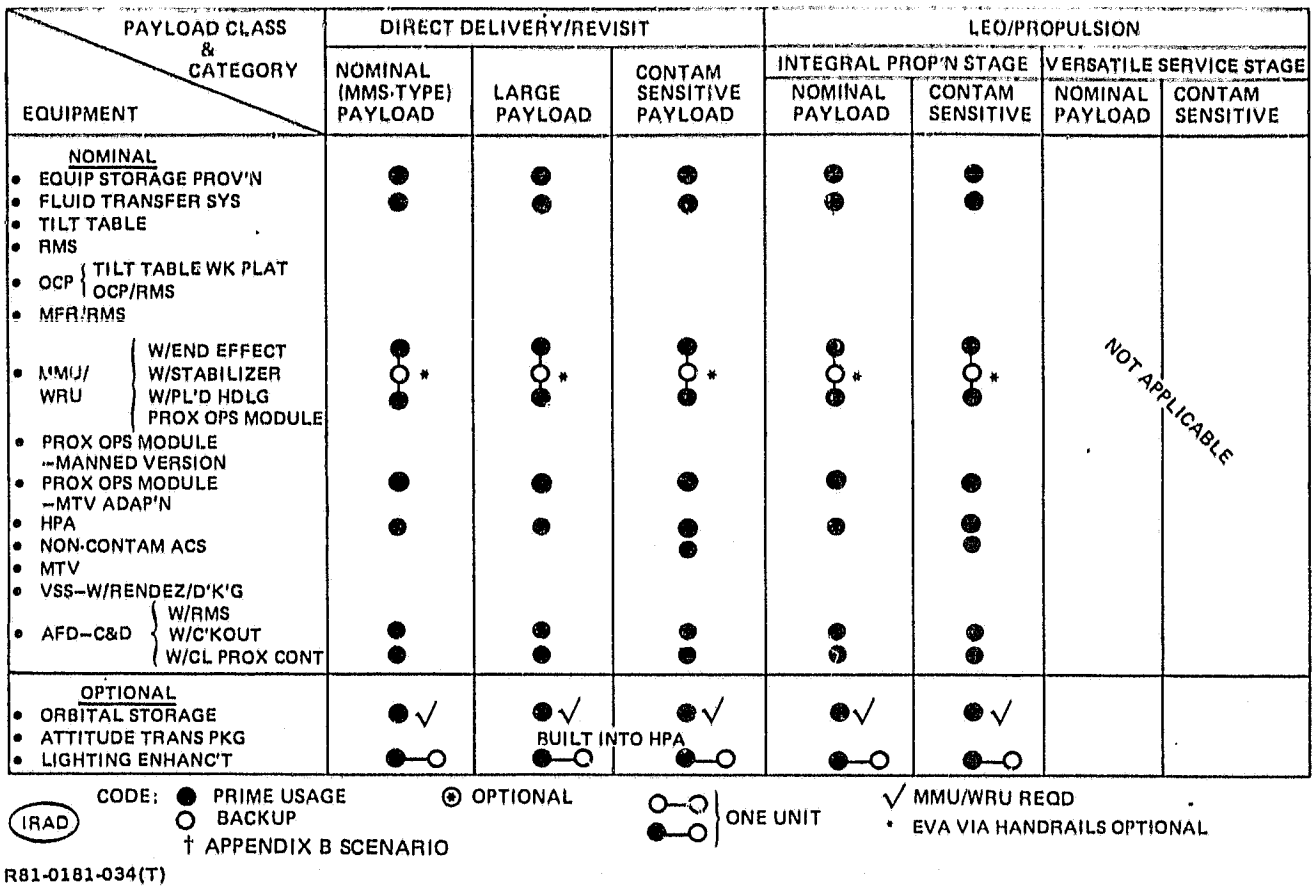



**Fig. 3.2-30 Revisit — Equipment Utilization Summary — Alternate Scenario No. 3 — RMS/HPA Usage — Unmanned Retrieval of Satellites at 1000 Ft Separation — RMS Inoperative**

3.2.2.5 Summary of Revisit Service Equipment and Usage

Figure 3.2-31 consolidates the equipment utilization summaries that apply to the 48 scenarios considered in the Revisit-Servicing Scenarios matrix. A total of 21 service equipment needs have been identified to cover the revisit scenarios shown in Fig. 3.2-31. Eighteen of the equipment needs represent nominal (or basic) equipment that would be carried in the satellite services inventory to cover both planned and contingency operations. Three of the equipment needs identified represent optional equipment/services which could be made available to the satellite user community. The service equipment needs identified for revisits are as follows:

(1) Equipment Storage — Provisions are needed for transport/stowage of components, modules, instruments, etc., to enable satellite maintenance, refurbishment, and reconfiguration. The wide variety of potential package geometries/masses may call for unique support arrangements for each satellite being serviced.

(2) Tilt Table — The FSS Cradle A' is used as a support structure for on-orbit satellite servicing within the confines of the Orbiter payload bay. The Cradle A'/satellite interface contains provisions for berthing/retention, umbilical connectors, and a rotational (turn table) mechanism to enable access to the satellite.

(3) Open Cherry Picker (OPC) Tilt Table Work Platform — A work platform can be adapted to the FSS Cradle A' to enable servicing of variable diameter/length satellites mounted on the Tilt Table. This capability, together with the 360° rotational feature provided with the Tilt Table, provides total access to all locations on a satellite.

(4) Open Cherry Picker/Remote Manipulator System (OCP/RMS) — The OCP is a movable work station controlled by an EVA astronaut on the tip of the RMS arm. Servicing capabilities include lighting, tool storage, a payload handling/transport device,

ORIGINAL PAGE IS
OF POOR QUALITY

48 SCENARIOS

| SCENARIO \ PAYLOAD CLASS & CATEGORY | DIRECT DELIVERY-REVISIT | | | LEO/PROPULSION - REVISIT | | | |
|---|---|---|---|---|---|---|---|
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAM SENSITIVE PAYLOAD | INTEGRAL PROP STAGE: NOMINAL PAYLOAD | INTEGRAL PROP STAGE: CONTAM SENSITIVE | VERSATILE SERV STAGE: NOMINAL PAYLOAD | VERSATILE SERV STAGE: CONTAM SENSITIVE |
| • NOMINAL (RMS/ TILT TABLE USAGE) | R-1 | • | R-5 | • | • | R-7 | • |
| • RMS INOPERATIVE | R-2 | • | • | • | • | • | • |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 1 (RMS/HPA USAGE) | R-3 | • | • | • | • | • | R-6 |
| • RMS INOPERATIVE | R-4 | • | • | • | • | • | • |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 2 (RMS/HPA, MANNED RETRIEVAL AT 1000') | • | • | • | • | • | NA | |
| • RMS INOPERATIVE | • | • | • | • | • | NA | |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | | — | |
| • ALTERNATE NO. 3 (RMS/nPA, UNMANNED RETRIEVAL AT 1000') | • | • | R-5 | • | • | NA | |
| • RMS INOPERATIVE | • | • | • | • | • | NA | |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | | — | |

NA = NOT APPLICABLE
R-N = SCENARIOS COMPLETED

R81-0181-017(T)

REVISIT – SERVICING
SCENARIOS MATRIX

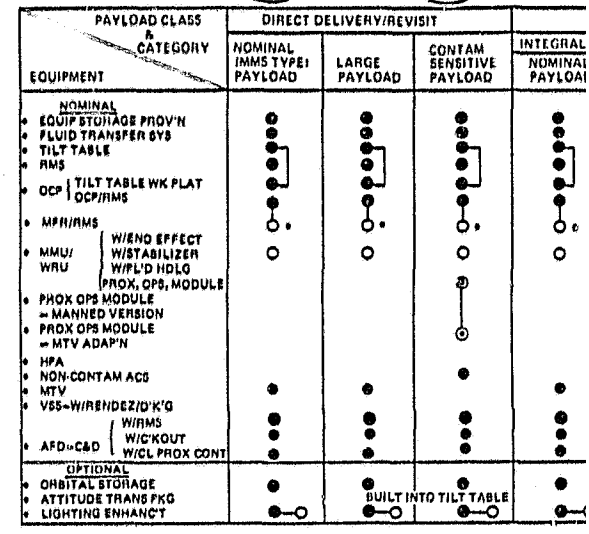
FOLDOUT FRAME

IRAD

R81-0181-035(T)

## NOMINAL SCENARIO

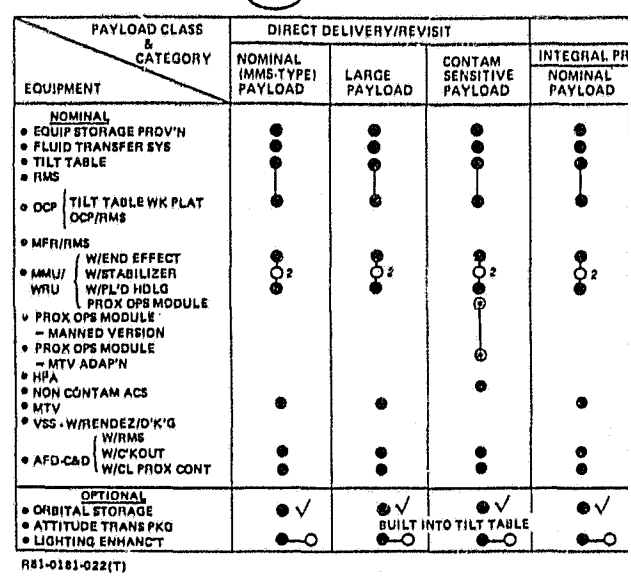
† R-1 R-5




R81-0181-021(T)

– RMS/TILT TABLE USAGE

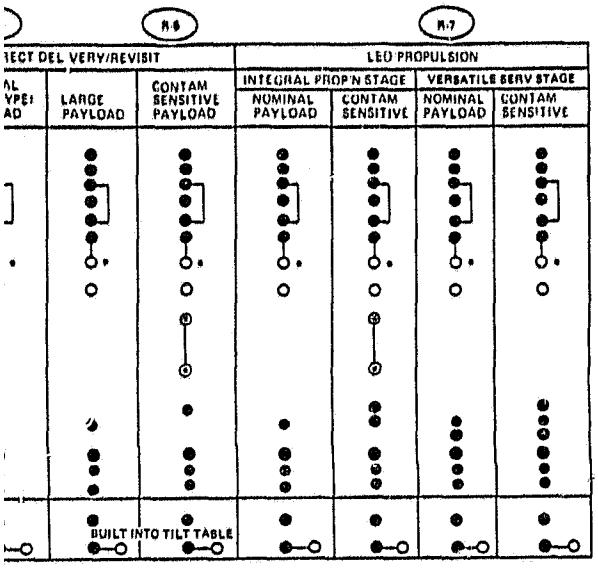
† R-2




R81-0181-022(T)

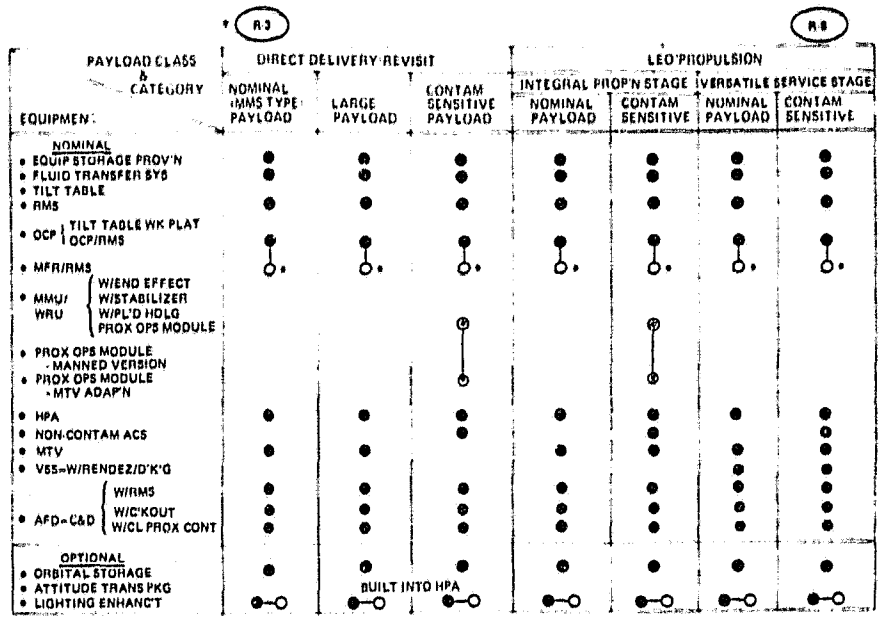
– RMS/TILT TABLE USAGE
– RMS INOPERATIVE

## NOMINAL SCENARIO

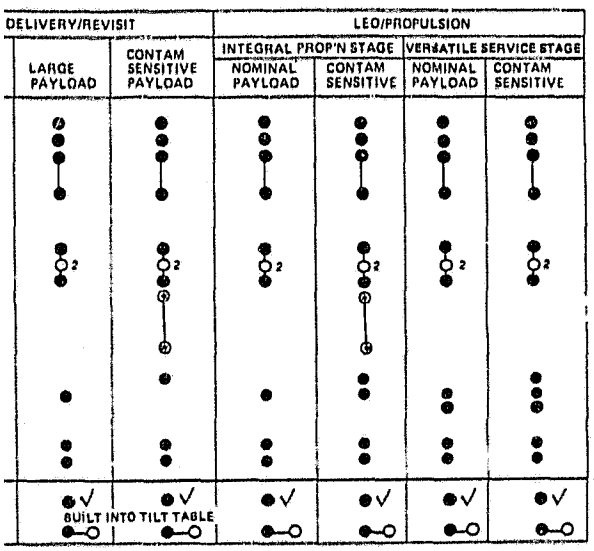



– RMS/TILT TABLE USAGE

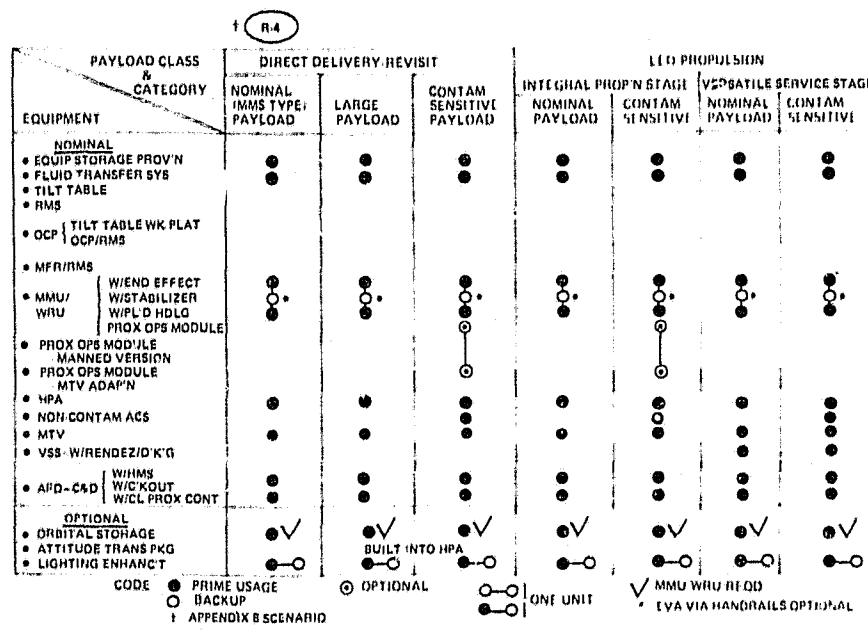
## ALTERNATE SCENARIO NO. 1




– RMS/HPA USAGE




– RMS/TILT TABLE USAGE
– RMS INOPERATIVE




– RMS/HPA USAGE
– RMS INOPERATIVE

Fig. 3.2-31(a) Service Equipment Utilization for Revisit Servicing Scenarios: Nominal Scenario; Alternate Scenario No. 1

FOLDOUT FRAME

48 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY/REVISIT | | | LEO/PROPULSION + REVISIT | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROP STAGE | | VERSATILE SERV STAGE | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAM SENSITIVE PAYLOAD | NOMINAL PAYLOAD | CONTAM SENSITIVE | NOMINAL PAYLOAD | CONTAM SENSITIVE |
| • NOMINAL (RMS/TILT TABLE USAGE) | R-1 | • | R-5 | • | • | R-7 | • |
| • RMS INOPERATIVE | R-2 | • | • | • | • | • | • |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 1 (RMS/HPA USAGE) | R-3 | • | • | • | • | • | R-8 |
| • RMS INOPERATIVE | R-4 | • | • | • | • | • | • |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLEAN" VEHICLE CLOSES | ORBITER CLOSES | "CLEAN" VEHICLE CLOSES | "CLEAN" VSS CLOSES | |
| • ALTERNATE NO. 2 (RMS/HPA, MANNED RETRIEVAL AT 1000') | • | • | • | • | • | NA | |
| • RMS INOPERATIVE | • | • | • | • | • | NA | |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | | — | |
| • ALTERNATE NO. 3 (RMS/HPA, UNMANNED RETRIEVAL AT 1000') | • | • | R-6 | • | • | NA | |
| • RMS INOPERATIVE | • | • | • | • | • | NA | |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | | — | |

NA = NOT APPLICABLE
R-N = SCENARIOS COMPLETED

R81-0181-017(T)

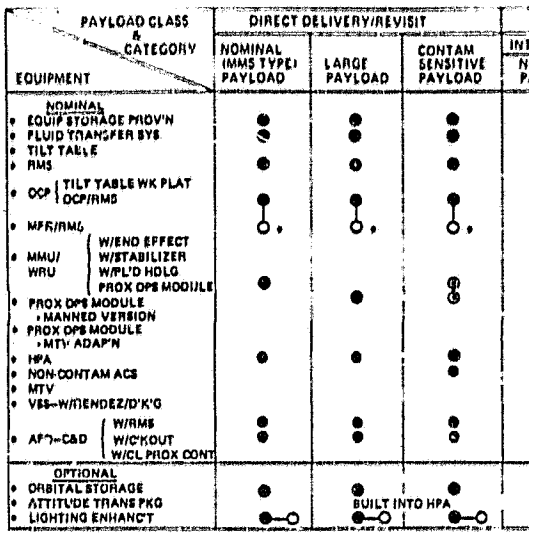
REVISIT - SERVICING
SCENARIOS MATRIX

FOLDOUT FRAME

IRAD

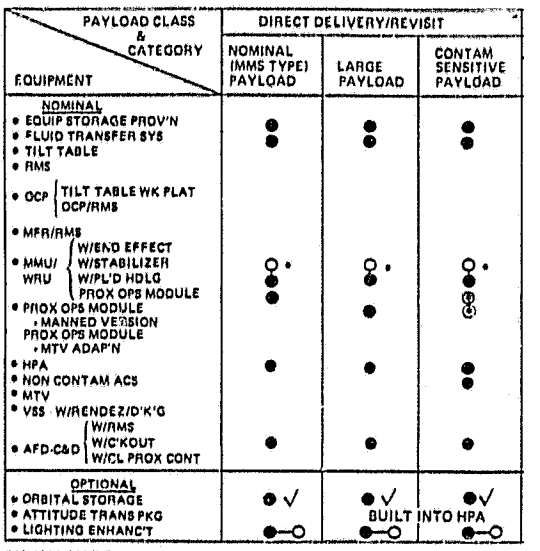
R81-0181-036(T)

## ALTERNATE SCENARIO




R81-0181-028(T)

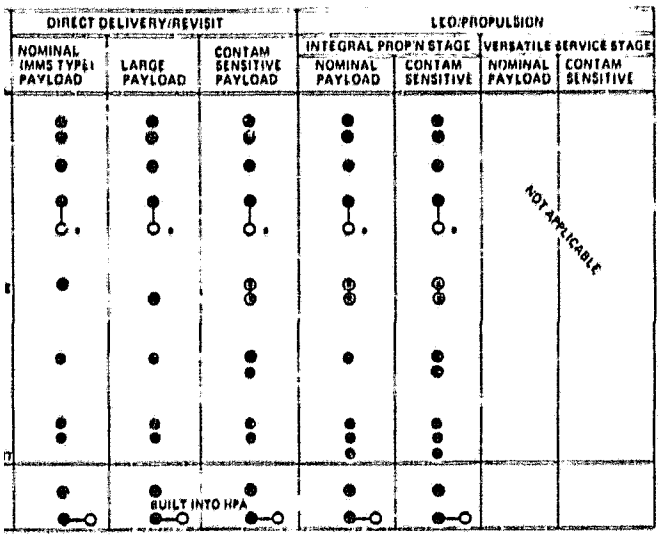
– RMS/HPA USAGE
– MANNED RETRIEVAL OF




R81-0181-029(T)

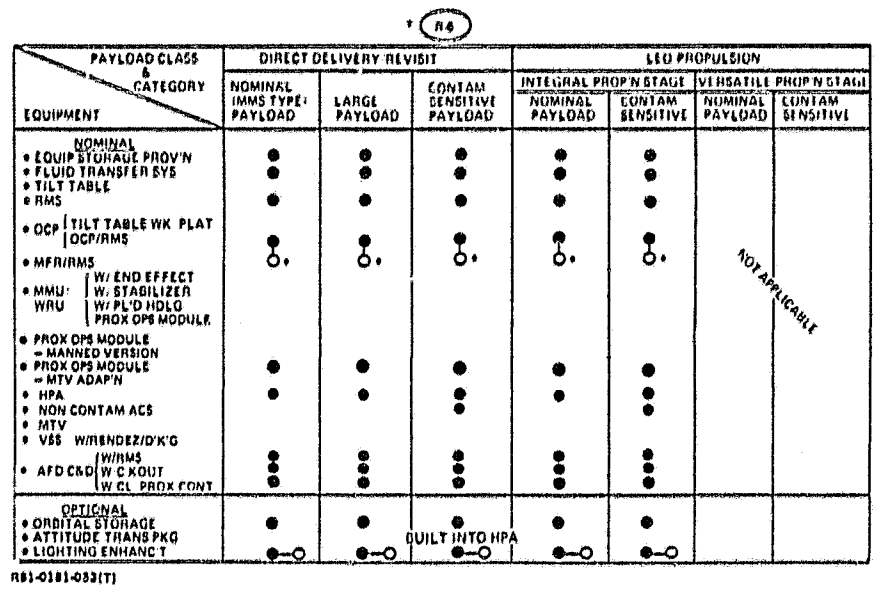
– RMS/HPA USAGE
– MANNED RETRIEVAL
– RMS INOPERATIVE

## ALTERNATE SCENARIO NO. 2

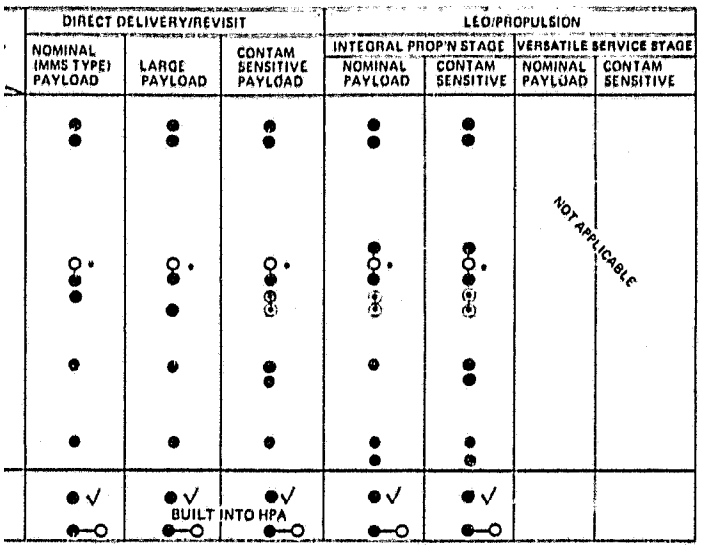



– RMS/HPA USAGE
– MANNED RETRIEVAL OF SAT'S

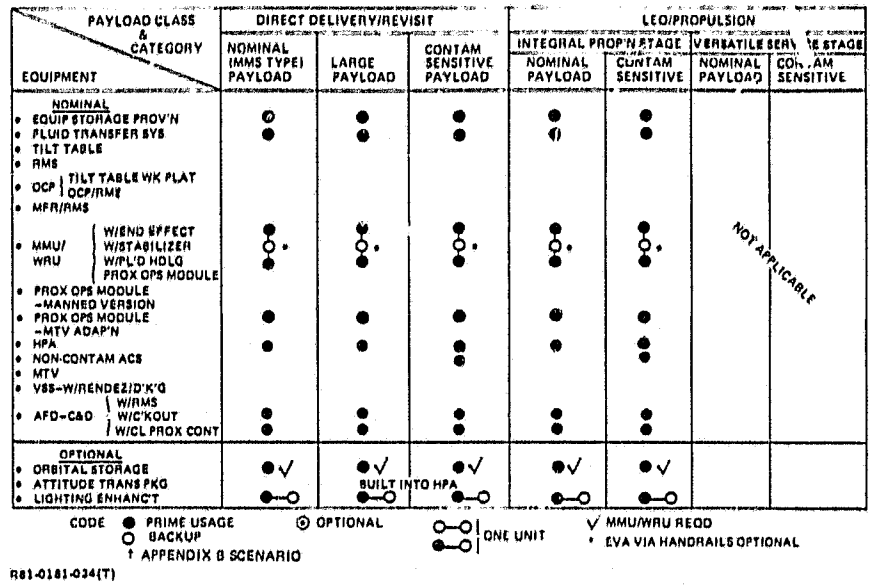
## ALTERNATE SCENARIO NO. 3




– RMS/HPA USAGE
– UNMANNED RETRIEVAL OF SAT'S




– RMS/HPA USAGE
– MANNED RETRIEVAL OF SAT'S
– RMS INOPERATIVE




– RMS/HPA USAGE
– UNMANNED RETRIEVAL OF SAT'S
– RMS INOPERATIVE

**Fig. 3.2-46(b) Service Equipment Utilization for Revisit Servicing Scenarios: Alternate Scenario No. 2; Alternate Scenario No. 3**

FOLDOUT FRAME 2

and a stabilizer to rigidly position the astronaut relative to a work site.

(5) Manipulator Foot Restraint (MFR)/RMS

The MFR/RMS serves as a backup for potential hangups of mechanical devices in the payload bay, and hangup situations associated with satellite appendage deployment. For those missions where an OCP is carried as part of the basic service equipment complement, the OCP/RMS would replace the backup functions of the MFR/RMS.

(6) Remote Manipulator System (RMS)

On revisit missions, the RMS is used to deploy the MTV for examining payloads prior to retrieval. It subsequently retrieves the payloads when within reach-distance of the RMS arm. The payloads are then placed on the Tilt Table or Handling and Positioning Aid for on-orbit servicing. The RMS is also used to support OCP and MFR utilization.

(7) Handling and Positioning Aid (HPA)

The HPA is used as a support structure for on-orbit satellite servicing outside of the confines of the Orbiter payload bay. Servicing can be accommodated by rotating turn-table provisions in the HPA and via a movable work station with translational and vertical motion capabilities to enable total access to all locations of a satellite. The HPA contains a standardized berthing and umbilical interface for checkout prior to satellite redeployment (following servicing), has a fluid coupling interface to transfer propellants, has provisions for an attitude/state vector transfer for all satellites, and provides the means to impart a $\Delta V$ to a satellite to effect Orbiter separation. Additionally, the "over-the-side" feature of

| | |
|---|---|
| | the HPA could enable full deployment of satellite appendages prior to release from the Orbiter. |
| (8) Fluid Transfer System | Provisions are needed for storage and transfer of propellants for satellites and the Versatile Service Stage (which is used to deliver/retrieve satellites beyond the nominal delivery altitude of the Orbiter). Fluids replenishment could involve both direct tankage/fluid replacement and transfer of propellants via a special fluid transfer system. The needs for either approach are dependent upon more definitive definitions of satellite(s) and propulsion stage requirements than are presently available. |
| (9) Noncontaminating Attitude Control System (ACS) | Orbiter servicing of contamination-sensitive satellites can be effected by providing a non-contaminating ACS package in the payload bay. The package would provide precision, long-term attitude control without the use of the Orbiter's Primary or Vernier reaction control systems. Alternatively, and if acceptable, the Orbiter could be placed into a free-drift mode. |
| (10-12) Aft Flight Deck Controls & Displays (AFD-C&D):<br>• RMS Control Panel<br>• Satellite C/O Panel<br>• Close Proximity Ops Panel | Controls and displays will be provided in the AFD for control of the RMS, for standardized satellite checkout and deployment, and for close proximity flight control of the MTV, Versatile Service Stage, and unmanned Proximity Operations Module. |
| (13) Maneuverable Television (MTV) | The MTV is used to remotely examine all satellites prior to Orbiter retrieval, and can also be deployed to view and record Versatile Service Stage propulsion firings. The system is flown by the Orbiter crew from the Aft Flight Deck, with video and telemetry transmission back to the Orbiter. |

(14) Proximity Operations Module (POM) - MTV Adaptation

The Orbiter can readily rendezvous with a satellite to within a 1000 ft distance. Unmanned retrieval of satellites within this 1000 ft range can be accomplished by a POM-MTV adaptation. Controlled by the crew in the Orbiter, the POM would be dispatched to capture the satellite and return it to within the reach distance of the RMS. It would be flown via TV (essentially using MTV equipment) and would effect capture via the satellite's RMS-compatible grapple fixture. The POM has been initially configured for retrieving satellites with masses up to 10,000 lb. It utilizes a non-contaminating cold gas propulsion system which provides three axes of control during free-flight and satellite towing operations.

(15) Proximity Operations Module (POM) - Manned Version

The Manned Version of the Proximity Operations Module was configured for retrieval of large satellites ($\sim$30,000 lb mass) within a 1000 ft range of the Orbiter. Our present satellite & services user model (S/SUM), however, projects a low usage rate for this POM-Manned Version. This suggests that large mass retrieval capability be designed in to the POM-MTV adaptation to minimize the number of new equipment developments, and to reduce user charges by accommodating satellite retrieval with high usage service equipment.

(16) Manned Maneuvering Unit/ Work Restraint Unit (MMU/WRU)

Adaptations of the WRU in conjunction with the MMU serve as the backup for RMS-inoperative situations for revisit service missions. A WRU adapted with an RMS snare end-effector would retrieve payloads within the local vicinity of the Orbiter and position the payloads on the Tilt Table or HPA for on-

orbit servicing. Further, a payload handling adaptation of the WRU would transport replacement equipment/modules from the payload bay to the work platform at the service site. To support hangups of mechanical devices in the payload bay and situations associated with satellite appendage deployment, a WRU adapted with a stabilizer would be deployed to allow manual release by an EVA astronaut. The three adaptations of the WRU (RMS snare end-effector, payload handling, stabilizer) referred to above, are implemented in terms of "kits" adaptable to a single WRU carried on the service mission.

(17) Proximity Operations Module (POM) - MMU/WRU Adaptation

Manned retrieval of satellites within a 1000 ft range can also be accomplished by a POM-MMU/WRU adaptation. An astronaut would fly the MMU/WRU to the satellite, capture it via the satellite's RMS-compatible grapple fixture, and tow the satellite to within the reach distance of the RMS. For near-term satellite retrieval missions, the POM-MMU/WRU adaptation appears to be the more readily available POM approach, since most of the major hardware elements exist or are in late stages of development. Downstream satellite retrieval missions would likely favor the POM-MTV adaptation.

(18) Versatile Service Stage (VSS):

- Retrieval & Rendezvous

The VSS retrieves satellites from higher energy LEO orbits not accessible directly by the Orbiter. It is equipped with a high performance propulsion system for performing large $\Delta V$ maneuvers and a clean-firing cold-gas propulsion system for close-in satellite retrieval and Orbiter close proximity operations. The VSS contains TV systems for satellite exami-

nation and to support remote control of the VSS-to-satellite docking/capture operation. Servicing of the satellite takes place on the Orbiter. After appropriate checkout of the satellite/VSS and refueling of the VSS, the payload is deployed from the Orbiter; the VSS then delivers the satellite to its operational orbit and returns again to the Orbiter. Following satellite capture, the VSS would return to the Orbiter and rendezvous within about 1000 ft. The close proximity flight control to RMS capture of the VSS/satellite is remotely controlled by the Orbiter crew. On-orbit refueling of the VSS would be accommodated by an appropriate fluid transfer system in the Orbiter payload bay. The VSS would also be designed to operate with a special front-end attachment (or "kit") to permit retrieval of satellites known to be oscillating or tumbling at rates higher than acceptable for docking by the VSS. The "kit" would enable the VSS to stabilize the "noncooperative satellite," follow with VSS docking/capture, and return to the Orbiter.

Optional Equipment

(19) Orbital Storage

Provides a means to leave the serviced satellite on-orbit for subsequent revisit/repair in the event of a malfunction detected during servicing and/or prior to redeployment which would render the satellite non-operational.

(20) Attitude Transfer Package

This unit provides a means for accurately transferring attitude reference data from the Orbiter Nav-base to satellites requiring accurate attitude/position information prior to deployment from the Orbiter.

| | |
|---|---|
| (21) Lighting Enhancement | Supplementary lighting or enhanced viewing capabilities are provided for nominal and backup EVA activities associated with revisit servicing missions. |

### 3.2.3 Earth Return

Figure 3.2-32 shows the matrix of earth return scenarios that were considered in the study and identifies ninety-eight scenarios as applicable. The scenarios with numerical designations (e.g., ER-1, ER-2, etc.) are those for which Level-1 sequences-of-events have been prepared and are provided in Appendix B. The Direct Delivery-Return class payloads cover retrieval and earth return of those satellites directly reachable by the Orbiter. The LEO/Propulsion-Return class payloads involve satellite retrieval from higher energy orbits followed by rendezvous with the Orbiter. The payload classes/categories shown are identical to those in the Revisit-Servicing Scenarios matrix in Fig. 3.2-13, with the addition of debris de-orbit and debris return categories and the cooperative/noncooperative satellite situations applicable to the respective payload categories. The earth return scenarios also reflect similar nominal and alternate cases, RMS inoperative situations, and close proximity operations as the Revisit-Servicing Scenarios matrix.

All scenarios again include backups for hangup of mechanical devices. The ER-9 scenario is highlighted in Fig. 3.2-32 because it will be addressed further in Section 3.2.3.3 (Alternate Earth Return Scenario #1) to illustrate the approach used to identify service equipment/usage for earth return missions.

#### 3.2.3.1 Nominal Earth Return Scenarios No. 1 - RMS Usage

The Nominal No. 1 series of scenarios referred to in the Earth Return Scenarios matrix (Ref: Fig. 3.2-32) represent scenarios in which the RMS is used to retrieve payloads and then stow the spacecraft in the Orbiter payload bay. The scenarios apply to the Direct Delivery-Return, and LEO/Propulsion-Return payload classes.

LEO/Propulsion class satellites compatible* with the Versatile Service Stage (VSS) would be captured and returned from their operational orbit to the vicinity of the Orbiter, where the close proximity operations would be remotely controlled by the Orbiter crew. The VSS's "clean burning" propulsion system would be used for these close-in operations to bring the satellite/VSS to within the RMS reach distance to effect capture.

---

*capable of being docked to the VSS

98 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) | ER-1 | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ER-2 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) | ● | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #1 (RMS/HPA USAGE) | ER-3 | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ER-4 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #2 (RMS/HPA USAGE-MANNED RETRIEVAL AT 1000') | ER-5 | ER-6 | ● | ● | N/A | ● | N/A |
| • RMS INOPERATIVE | ● | ● | ● | ● | N/A | ● | N/A |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | VSS-CL | MD-VE | CL-VSS-CL |
| • ALTERNATE #3 (RMS/HPA USAGE-UNMANNED RETRIEVAL AT 1000') | ● | ● | ER-7 | ● | N/A | ● | N/A |
| • RMS INOPERATIVE | ● | ● | ER-8 | ● | N/A | ● | N/A |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | VSS-CL | UN-VE | CL-VSS-CL |

| PAYLOAD CLASS & CATEGORY / SCENARIO | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #1 (RMS/HPA USAGE) | ER-9 | ER-10 | ● | ● | ER-11 | ER-12 |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #2 (RMS/HPA USAGE - MANNED RETRIEVAL AT 1000') | N/A | N/A | N/A | N/A | N/A | N/A |
| • RMS INOPERATIVE | N/A | N/A | N/A | N/A | N/A | N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #3 (RMS/HPA USAGE - UNMANNED RETRIEVAL AT 1000') | N/A | N/A | N/A | N/A | N/A | N/A |
| • RMS INOPERATIVE | N/A | N/A | N/A | N/A | N/A | N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |

NOTE: – FOR NON-COOPERATIVE SATELLITES THAT ARE VSS-COMPATIBLE (CAPABLE OF DOCKING TO VSS) AND STS-COMPATIBLE (E.G. OUTFITTED WITH RMS GRAPPLE FITTING), IT IS ASSUMED THAT THE DEGREE OF SATELLITE INSTABILITY IS NOT THAT SEVERE AS TO PRECLUDE CAPTURE BY TECHNIQUES APPLICABLE TO COOPERATIVE SATELLITES

– THE UNLIKELY SITUATION OF VERY HIGH TUMBLE RATES (E.G. ~ 10 RPM) WOULD BE COVERED BY THE DEBRIS RETRIEVAL/RETURN SCENARIO, AS WOULD APPLY TO SATELLITES TO BE RETRIEVED/RETURNED WHICH ARE NOT STS-COMPATIBLE (E.G. OAO)

IRAD

R81-0181-037(T)

CODE: OR-CL = ORBITER CLOSES
VSS-CL = VSS CLOSES
CL-VSS-CL = CLEAN VSS CLOSES
CL-VE = CLEAN VEHICLE CLOSES
MD-VE = MANNED VEHICLE CLOSES
UN-VE = UNMANNED VEHICLE CLOSES

**Fig. 3.2-32 Earth Return Service Scenarios**
**(all scenarios include backups for hangups of mechanical devices)**

"Noncooperative" VSS-compatible satellites that are STS-compatible (e.g., outfitted with an RMS grapple fitting) would be captured by a VSS adapted with a front-end "kit" capable of sufficiently stabilizing the satellite to enable VSS-to-satellite docking, followed by return to the Orbiter/RMS capture. Debris return or deorbit situations would be handled by another VSS front end "kit" designed to capture uncooperative/unstable spacecraft. Following capture, the VSS could impart a $\Delta V$ to effect a controlled reentry of the debris, or return/rendezvous with the Orbiter, with the VSS being "flown-in" by the Orbiter crew to enable RMS capture.

"Cooperative" LEO/Propulsion class satellites, with integral stages, would return from their operational orbit to the Orbiter's nominal orbit to enable direct retrieval/capture by the Orbiter. "Noncooperative" LEO/Propulsion class satellites, with integral stages, would be captured by a VSS adapted with the debris retrieval front-end "kit." Following capture, the satellite/VSS would rendezvous with the Orbiter to effect RMS capture.

For contamination-sensitive payloads (excluding the VSS-compatible satellites) a "clean burning" Proximity Operations Module (manned or unmanned) would be deployed when the payload is within 1000 ft of the Orbiter to bring the satellite to within the RMS reach distance.

Figure 3.2-33 shows the nominal and backup service equipment applicable to the earth return scenarios represented by the satellite classes/categories indicated. The equipment complements vary considerably depending upon the type of payload being retrieved. An MTV is deployed to examine all payloads prior to retrieval, except for the contamination-sensitive payloads wherein a Proximity Operations Module (containing viewing capabilities) is deployed. For large spacecraft, a Payload Installation/Deployment Aid (PIDA) is used to position the satellite in its retention structure. A Versatile Service Stage (VSS) is used in eight scenarios; six basic and two involving retrieval of noncooperative nominal and contamination-sensitive satellites with integral propulsion stages. Exclusive of AFD Controls/Displays, between four and seven items of service equipment are needed to cover these earth return service scenarios.

† (ER-1)

| EQUIPMENT \ PAYLOAD CLASS & CATEGORY | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION - RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| NOMINAL | | | | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | | | | | | | |
| • TILT TABLE | | ● | | | | | |
| • PIDA | | | | | | | |
| • RMS | ● | ● | ● | ● | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT / OCP/RMS | | | | | | | |
| • MFR/RMS | ○* | ○* | ○* | ○* | ○* | ○* | ○* |
| • MMU/WRU { W/END EFFECT / W/STABILIZER / PROX OPS MODULE | ○ | | ○ ⊙ | ○ | ○ | ○ ⊙ | ○ |
| • PROX OPS MODULE – MANNED VERSION | | | ● | | | ● | |
| • PROX OPS MODULE – MTV ADAP'N | | | | | | | |
| • HPA | | | | | | | |
| • NON-CONTAM ACS | | | ● | | | ● | ● |
| • MTV | ● | ● | | ● | ● | | ● |
| • VSS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE | | | | | ● | | ● |
| • AFD-C&D { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL | ● ● ● | ● ● ● | ● ● ● | ● ● ● | ● ● ● | ● ● ● | ● ● ● |

| EQUIPMENT \ PAYLOAD CLASS & CATEGORY | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| NOMINAL | | | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● | | |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ | | ● |
| • EQUIP STORAGE PROVISIONS | | | | | | ● |
| • TILT TABLE | | | | | | |
| • PIDA | | | | | | |
| • RMS | ● | ● | ● | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT / OCP/RMS | | | | | | |
| • MFR/RMS | ○* | ○* | ○* | ○* | ○* | ○* |
| • MMU/WRU { W/END EFFECT / W/STABILIZER / PROX OPS MODULE | ○ | ○ | ○ | ○ | | ○ |
| • PROX OPS MODULE – MANNED VERSION | | | | | | |
| • PROX OPS MODULE –MTV ADAP'N | | | | | | |
| • HPA | | | | | | |
| • NON-CONTAM ACS | | | ● | ● | | |
| • MTV | ● | ● | ● | ● | ● | ● |
| • VPS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE | ● | ● | ● | ● | ● | ● |
| • AFD-C&D { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL | ● ● ● | ● ● ● | ● ● ● | ● ● ● | ● | ● |

CODE: ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL { ONE UNIT *EVA VIA HANDRAILS OPTIONAL

(IRAD) † APPENDIX B SCENARIO

R81-0181-038(T)

Fig. 3.2-33 Earth Return – Equipment Utilization Summary – Nominal Scenario No. 1 – RMS Usage

Figure 3.2-34 presents the equipment complements for the same earth return scenarios represented by the Nominal No. 1 case, but now the RMS is inoperative. The same basic equipment complements apply as in Fig. 3.2-33, but now the MMU/WRU variations are again necessary to complete the missions. Note that a second MMU/WRU with stabilizer is also needed for all of these scenarios. Exclusive of AFD Controls/Displays, between four and six items of service equipment are needed to cover these earth return service scenarios.

3.2.3.2 Nominal Earth Return Scenarios No. 2 - RMS/Tilt Table Usage

The Nominal No. 2 series of scenarios referred to in the Earth Return Scenarios matrix (Ref: Fig. 3.2-32) represents scenarios in which the RMS is used to retrieve satellites and place them on a Tilt Table for checkout/appendage or equipment removal. The Tilt Table is also used as a mechanism to rotate the satellite into its retention structure for return to earth. The scenarios apply to the Direct Delivery-Return and LEO/Propulstion-Return payload classes. The close proximity and retrieval operations associated with the payload classes/categories are the same as with the Nominal Earth Return Scenarios No. 1 (Sec. 3.2.3.1).

Figure 3.2-35 shows the nominal and backup service equipment applicable to the earth return scenarios represented by the satellite classes/categories indicated. The equipment complements are comparable to the Nominal No. 1 RMS usage situation (Ref: Fig. 3.2-32), but with the addition of the Tilt Table and OCP-Tilt Table Work Platform (which is considered as a single unit of equipment). Exclusive of the AFD Controls/Displays, between five and eight items of service equipment are needed to cover these earth return service scenarios.

Figure 3.2-36 presents the equipment complements for the same earth return scenarios represented by the Nominal No. 2 case, but now with the RMS inoperative. The same basic equipment complements apply as in Fig. 3.2-35, but now the MMU/WRU variations are again needed to complete the missions. Note that a second MMU/WRU with stabilizer could also be called for, although EVA via handrails in the payload bay might also be used for these backup retention latch hangup situations. Exclusive of AFD Controls/Displays, between four and seven items of service equipment are needed to cover these earth return service scenarios.

† (ER-2)

| EQUIPMENT \ PAYLOAD CLASS & CATEGORY | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION - RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| NOMINAL | | | | | | | |
| • RETENTION STRUCTURE | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ |
| • "SPECIAL" RETENTION STR | | | | | | | |
| • EQUIP STORAGE PROVISIONS | | ● | | | | | |
| • TILT TABLE | | | | | | | |
| • PIDA | | | | | | | |
| • RMS | | | | | | | |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | | | | | |
| • MFR/RMS | | | | | | | |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 |
| • PROX OPS MODULE – MANNED VERSION | | | ⊙ | | | ⊙ | |
| • PROX OPS MODULE – MTV ADAP'N | | | ● | | | ● | ● |
| • HPA | | | | | | | |
| • NON-CONTAM ACS | | | | | | | |
| • MTV | ● | ● | | ● | ● | | |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | | | | ● ● | | ● ● |
| • AFD-C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● |

| EQUIPMENT \ PAYLOAD CLASS & CATEGORY | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| NOMINAL | | | | | | |
| • RETENTION STRUCTURE | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | | ● ● |
| • "SPECIAL" RETENTION STR | | | | | | |
| • EQUIP STORAGE PROVISIONS | | | | | | |
| • TILT TABLE | | | | | | |
| • PIDA | | | | | | |
| • RMS | | | | | | |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | | | | |
| • MFR/RMS | | | | | | |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 | ●-○ ○ 2 |
| • PROX OPS MODULE – MANNED VERSION | | | | | | |
| • PROX OPS MODULE – MTV ADAP'N | | | | | | |
| • MANNED TOW TUG | | | | | | |
| • UNMANNED TOW TUG | | | | | | |
| • HPA | | | | | | |
| • NON-CONTAM ACS | | | ● | ● | | |
| • MTV | ● | ● | ● | ● | ● | ● |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | ● | ● | ● | ● | ● ● | ● ● |
| • AFD-C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● ● | ● ● | ● ● | ● ● | ● | ● |

(IRAD)

CODE: ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL ○○/●○ ONE UNIT *EVA VIA HANDRAILS OPTIONAL
○2 SECOND MMU/WRU REQ'D † APPENDIX B SCENARIO

R81-0181-039(T)

Fig. 3.2-34 Earth Return – Equipment Utilization Summary – Nominal Scenario No. 1 – RMS Usage – RMS Inoperative

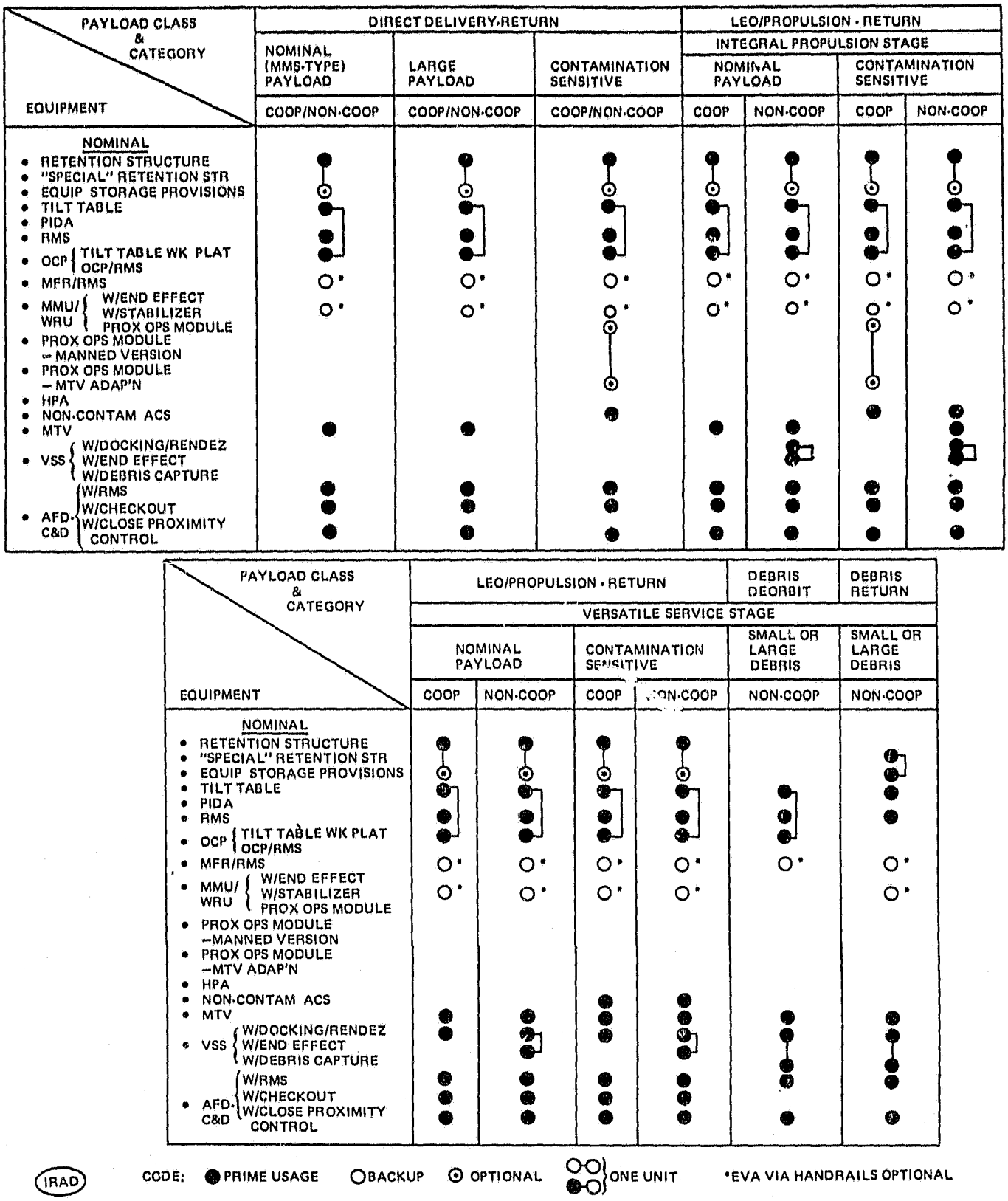
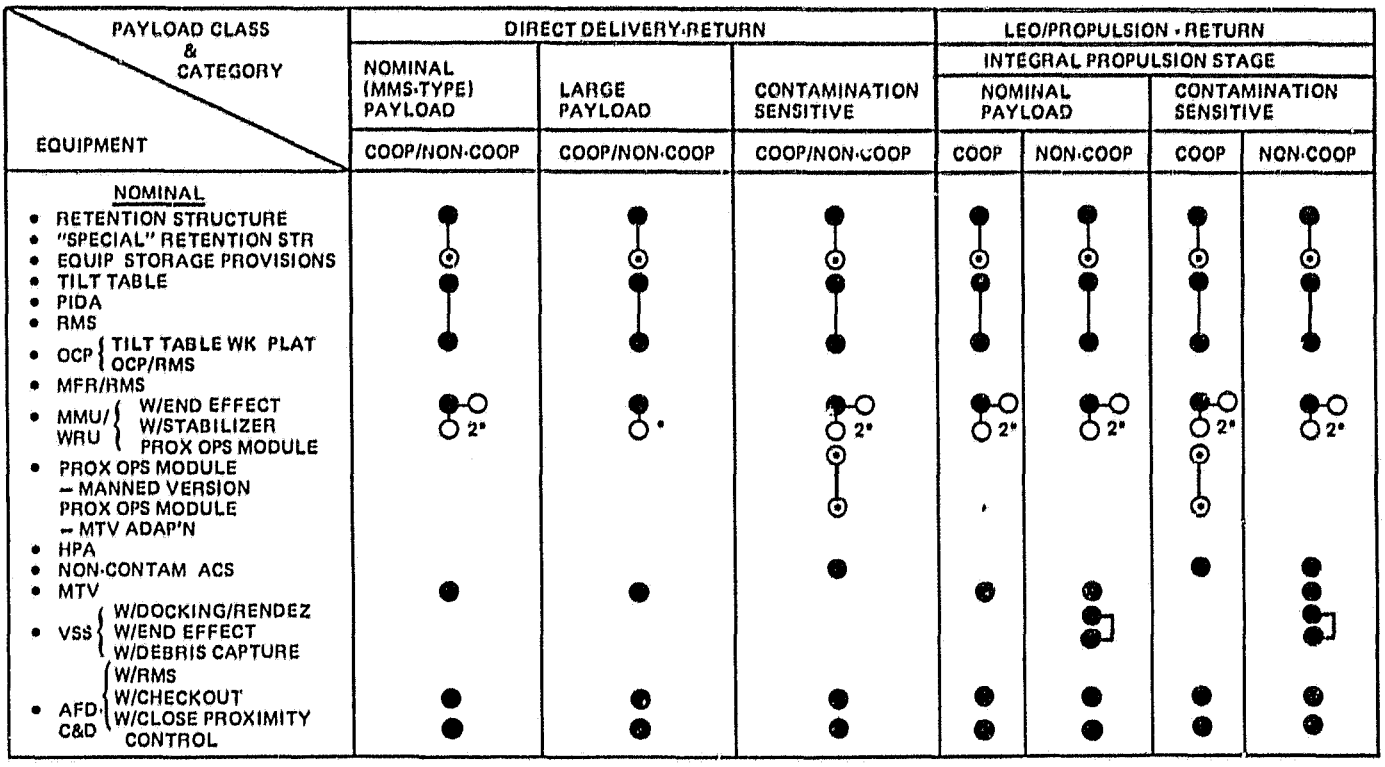
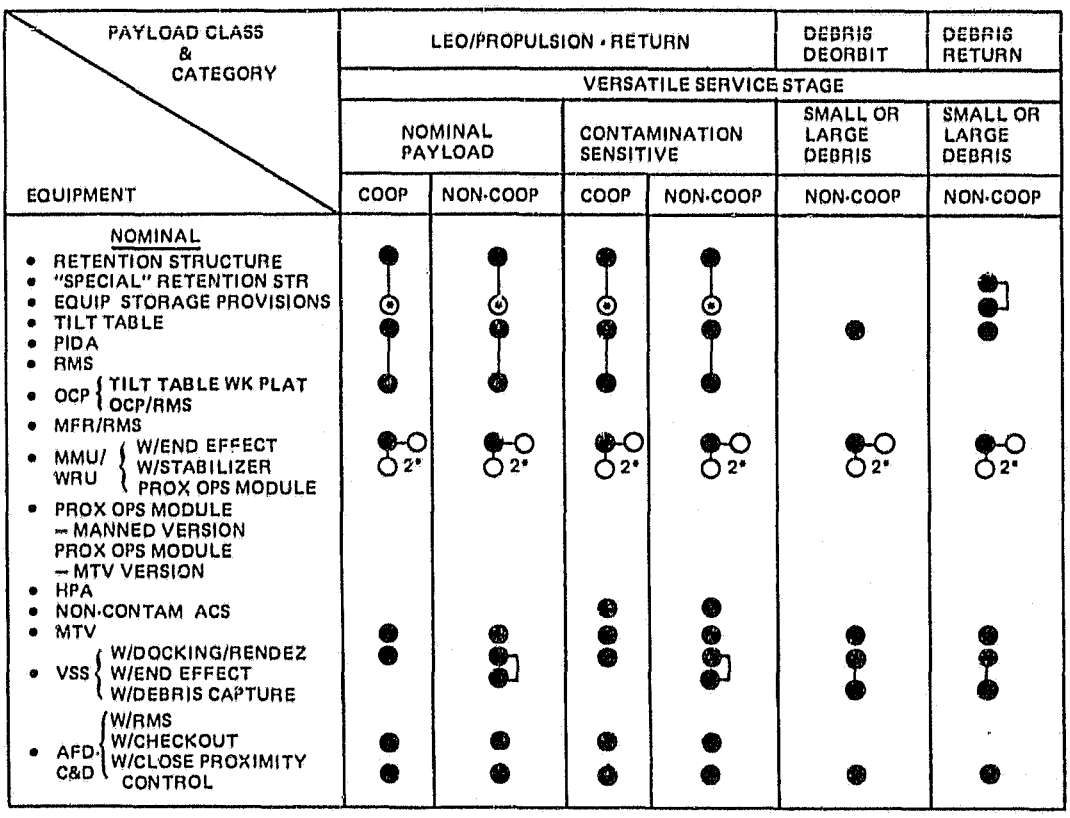



Fig. 3.2-35 Earth Return — Equipment Utilization Summary — Nominal Scenario No. 2 — RMS/Tilt Table Usage




IRAD

CODE: ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL ○○ ONE UNIT *EVA VIA HANDRAILS OPTIONAL
○² SECOND MMU/WRU REQD

R81-0181-041(T)

Fig. 3.2-36 Earth Return — Equipment Utilization Summary — Nominal Scenario No. 2 — RMS/Tilt Table Usage — RMS Inoperative

### 3.2.3.3 Alternate Earth Return Scenarios No. 1 - RMS/HPA Usage

The Alternate No. 1 series of scenarios referred to in the Earth Return Scenarios matrix (Ref. 3.2-32) represents scenarios in which the RMS is used to retrieve payloads and place them on a Handling & Positioning Aid (HPA) for final checkout/appendage or equipment removal, prior to RMS stowage of the payload in the Orbiter payload bay.

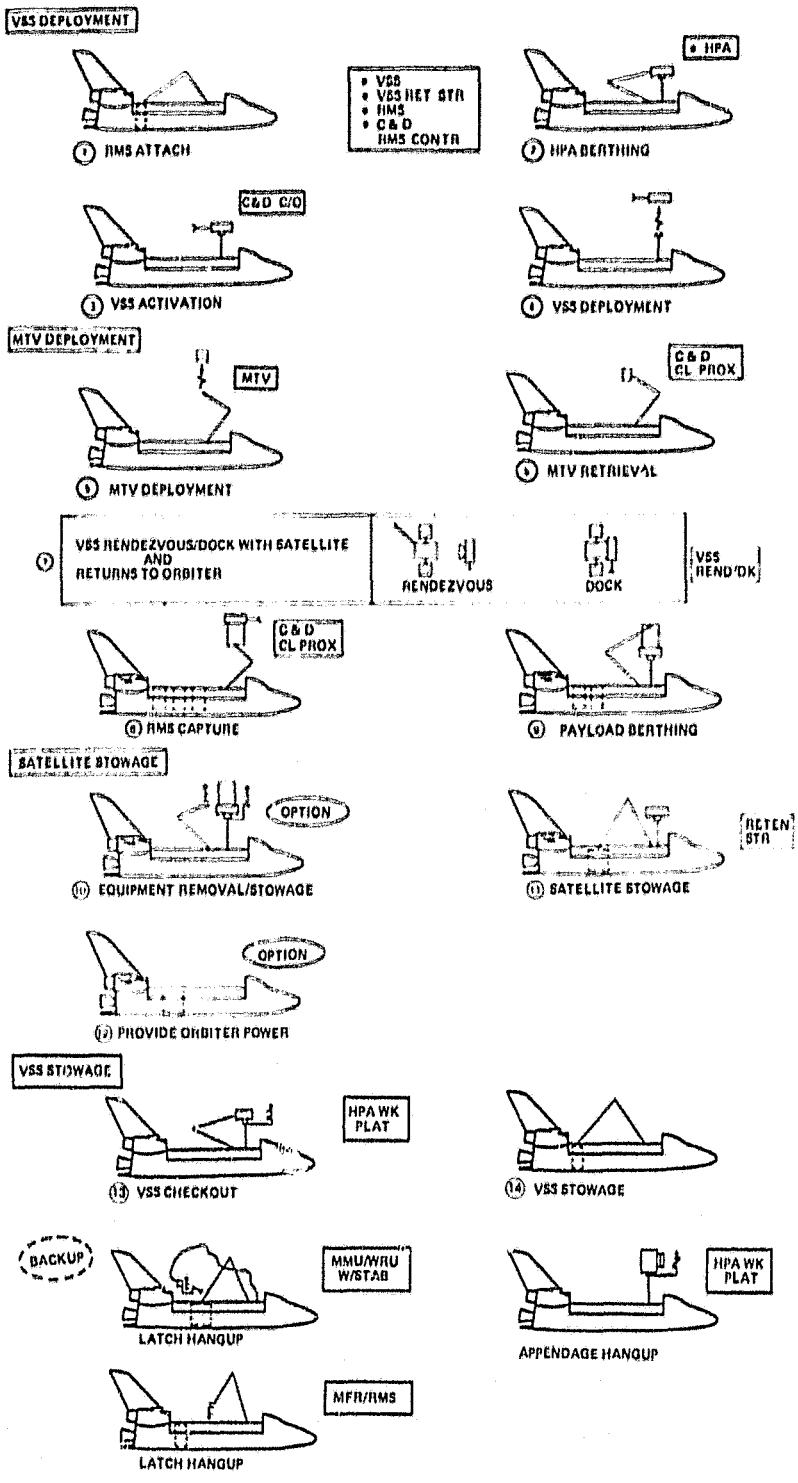
The scenarios apply to the Direct Delivery-Return, and LEO/Propulsion-Return payload classes. The close proximity and retrieval operations associated with the payload classes/categories are again the same as with Nominal Earth Return Scenario No. 1 (Sec. 3.2.3.1) and No. 2 (Sec. 3.2.3.2). As shown in the Earth Return Scenarios matrix, six Level-1 sequences-of-events were prepared (ER-3, ER-4, ER-9, ER-10, ER-11, ER-12) to aid in surfacing equipment utilizations. The ER-9 scenarios will be elaborated further to illustrate the process utilized.

Figure 3.2-37 shows the ER-9 Level-1 earth return sequence-of-events for the LEO/Propulsion payload class, nominal payload (MMS-type), in which a satellite is retrieved from its operational orbit and returned to the Orbiter by the VSS to effect RMS capture. Service equipment needs associated with a particular event are again highlighted, as was illustrated for previous sequences-of-events charts. The initial events call for:

- Versatile Service Stage (VSS) and its retention structure within the Orbiter
- Remote Manipulator System (RMS) and associated AFD Controls/Displays
- Handling & Positioning Aid (HPA)
- AFD Controls/Displays for checkout of the VSS
- Maneuverable Television (MTV) to view VSS firing and to examine the VSS and the satellite prior to "flying-in" the VSS within the RMS reach distance
- AFD Controls/Displays for close proximity flight control of the MTV.

Subsequent operations identify:

- VSS capabilities to rendezvous/dock with the satellite
- AFD Controls/Displays for close proximity flight control of the VSS
- Retention structure for satellite stowage
- Options to enable removal/stowage of satellite equipment and, potentially, to provide power to the satellite during the earth return flight




R81-0181-042(T)

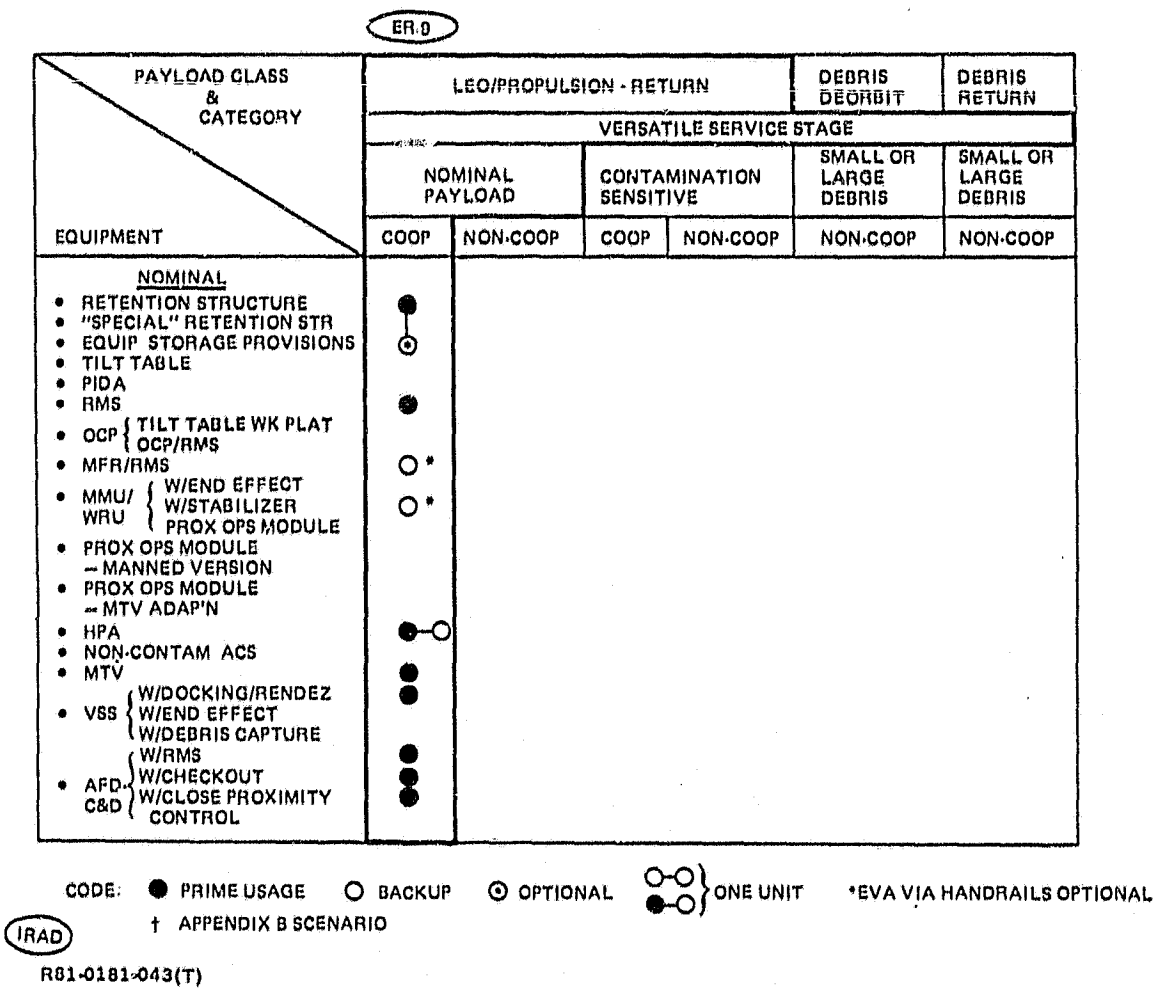
**Fig. 3.2-37 ER9 Earth Return — Alternate Scenario No. 1 — LEO/Propulsion Payload Class — Cooperative Nominal Payload — RMS/HPA Usage — VSS Application**

- HPA work platform for servicing the VSS prior to stowage.

Backup situations identify the following equipment needs:

- MMU/WRU with stabilizer to assist with a latch hangup during stowage of the satellite
- MFR/RMS to cover a latch hangup associated with the VSS
- HPA work platform (also identified above) to assist a potential satellite appendage hangup.

The equipment usage segment for the ER-9 scenario is shown highlighted in Fig. 3.2-38, within the overall format being used to identify equipment usage for all the scenarios applicable to this Alternate No. 1 case.




R81-0181-043(T)

Fig. 3.2-38 ER9 Earth Return – Equipment Utilization Summary – Alternate Scenario No. 1 – RMS/HPA Usage

Figure 3.2-39 repeats the original Earth Return Scenarios matrix (Ref: Fig. 3.2-32), but highlights the strip of thirteen scenarios applicable to this RMS/HPA usage situation.

Figure 3.2-40 summarizes the equipment utilizations for the scenarios emphasized in Fig. 3.2-39. Shown are the nominal and backup service equipment for these thirteen earth return scenarios. Also identified are the Level-1 sequences-of-events (ER-3, ER-9, ER-10, ER-11, ER-12) that were prepared to aid in surfacing the equipment identifications shown, and can be correlated to the scenarios found in Appendix B. The equipment complements are the same as the Nominal No. 2 RMS/Tilt Table usage situation (Ref: Fig. 3.2-35), but with the HPA replacing the Tilt Table/OCP-Tilt Table Work Platform. Exclusive of the AFD Controls/Displays, between five and eight items of service equipment are needed to cover these earth return service scenarios.

Figure 3.2-41 presents the equipment complements for the same earth return scenarios represented by the Alternate No. 1 case, but now with the RMS inoperative. The same basic equipment complements apply as in Fig. 3.2-40, but now the MMU/WRU variations are again needed to complete the missions. Note that a second MMU/WRU with stabilizer could also be called for, although EVA via handrails in the payload bay might also be used for these backup retention latch hangup situations. Exclusive of AFD Controls/Displays, between five and seven items of service equipment are needed to cover these earth return service scenarios.

### 3.2.3.4 Alternate Earth Return Scenarios No. 2 - RMS/HPA Usage - Manned Retrieval at 1000 ft Separation

The Alternate No. 2 series of scenarios referred to in the Earth Return Scenarios matrix (Ref: Fig. 3.2-32) represent scenarios where the Orbiter would rendezvous within 1000 ft of a payload. A manned Proximity Operations Module (POM) is then dispatched to retrieve and bring the payload within RMS reach distance. The payload is then captured by the RMS and placed on the Handling/Positioning Aid for final checkout/appendage or equipment removal prior to RMS stowage of the payload in the Orbiter payload bay.

The scenarios apply to the Direct Delivery-Return and LEO/Propulsion-Return payload classes. (Only the cooperative payloads with integral propulsion are considered since the balance of the LEO/Propulsion payload categories would be handled via Versatile Service Stage usage which were covered in Alternate Scenarios No. 1.) The satellite; with its integral stage, would return from its operational orbit to the Orbiter's

| SCENARIO \ PAYLOAD CLASS & CATEGORY | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) | ER-1 | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ER-2 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) | ● | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #1 (RMS/HPA USAGE) | ER-3 | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ER-4 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #2 (RMS/HPA USAGE-MANNED RETRIEVAL AT 1000') | ER-5 | ER-6 | ● | ● | [illegible] | ● | N/A |
| • RMS INOPERATIVE | ● | ● | ● | ● | N/A | ● | N/A |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | VSS-CL | MD-VE | CL-VSS-CL |
| • ALTERNATE #3 (RMS/HPA USAGE-UNMANNED RETRIEVAL AT 1000') | ● | ● | ER-7 | ● | N/A | ● | N/A |
| • RMS INOPERATIVE | ● | ● | ER-8 | ● | N/A | ● | N/A |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | VSS-CL | UN-VE | CL-VSS-CL |

| SCENARIO \ PAYLOAD CLASS & CATEGORY | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #1 (RMS/HPA USAGE) | ER-9 | ER-10 | ● | ● | ER-11 | ER-12 |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #2 (RMS/HPA USAGE - MANNED RETRIEVAL AT 1000') | N/A | N/A | N/A | N/A | N/A | N/A |
| • RMS INOPERATIVE | N/A | N/A | N/A | N/A | N/A | N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #3 (RMS/HPA USAGE - UNMANNED RETRIEVAL AT 1000') | N/A | N/A | N/A | N/A | N/A | N/A |
| • RMS INOPERATIVE | N/A | N/A | N/A | N/A | N/A | N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |

NOTE: • FOR NON-COOPERATIVE SATELLITES THAT ARE STS-COMPATIBLE (E.G. OUTFITTED WITH RMS GRAPPLE FITTING), IT IS ASSUMED THAT THE DEGREE OF SATELLITE INSTABILITY TO AFFECT CAPTURE IS STILL CAPTURABLE BY THE SAME TECHNIQUES APPLIED TO COOPERATIVE SATELLITES
• THE UNLIKELY SITUATION OF VERY HIGH TUMBLE RATES (E.G. ~ 10 RPM) WOULD BE COVERED BY THE DEBRIS RETRIEVAL/RETURN SCENARIO, . . AS WOULD APPLY TO SATELLITES TO BE RETRIEVED/RETURNED WHICH ARE NOT STS-COMPATIBLE (E.G. OAO)

IRAD

R81-0181-044(T)

CODE: OR-CL = ORBITER CLOSES; VSS-CL = VSS CLOSES; CL-VSS-CL = CLEAN VSS CLOSES; CL-VE = CLEAN VEHICLE CLOSES; MD-VE = MANNED VEHICLE CLOSES; UN-VE = UNMANNED VEHICLE CLOSES

**Fig. 3.2-39 Earth Return Servicing Scenarios — Alternate Scenario No. 1 Emphasis — RMS/HPA Usage**
**(all scenarios include backups for hangups of mechanical devices)**

† ER-3

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION - RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| NOMINAL | | | | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | | | | | | | |
| • TILT TABLE | | | | | | | |
| • PIDA | | | | | | | |
| • RMS | ● | ● | ● | ● | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | | | | | |
| • MFR/RMS | ○* | ○* | ○* | ○* | ○* | ○* | ○* |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ○* | | ○* | ○* | ○* | ○* | ○* |
| • PROX OPS MODULE – MANNED VERSION | | | ⊙ | | | ⊙ | |
| • PROX OPS MODULE – MTV ADAP'N | | | ● | | | ● | |
| • HPA | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ |
| • NON-CONTAM ACS | | | ● | | | ● | |
| • MTV | ● | ● | | ● | ● | | ● |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | | | | ● | | ● |
| • AFD/C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● | ● | ● | ● | ● | ● | ● |
| | ● | ● | ● | ● | ● | ● | ● |
| | ● | ● | ● | ● | ● | ● | ● |

ER-9 ER-10 ER-11 ER-12

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| NOMINAL | | | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● | | |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ | | ● |
| • EQUIP STORAGE PROVISIONS | | | | | | |
| • TILT TABLE | | | | | | |
| • PIDA | | | | | | |
| • RMS | ● | ● | ● | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | | | | |
| • MFR/RMS | ○* | ○* | ○* | ○* | ○* | ○* |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ○* | ○* | ○* | ○* | | ○* |
| • PROX OPS MODULE – MANNED VERSION | | | | | | |
| • PROX OPS MODULE – MTV ADAP'N | | | | | | |
| • HPA | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ |
| • NON-CONTAM ACS | ● | ● | ● | ● | | |
| • MTV | ● | ● | ● | ● | ● | ● |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | ● | | ● | | |
| • AFD/C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● | ● | ● | ● | ● | ● |
| | ● | ● | ● | ● | ● | ● |
| | ● | ● | ● | ● | ● | ● |

IRAD

CODE: ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL ○—○ ONE UNIT *EVA VIA HANDRAILS OPTIONAL
† APPENDIX B SCENARIO

R81-0181-045(T)

Fig. 3.2-40 Earth Return - Equipment Utilization Summary — Alternate Scenario No. 1 — RMS/HPA Usage

† (ER-4)

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION - RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| NOMINAL | | | | | | | |
| • RETENTION STRUCTURE | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ |
| • "SPECIAL" RETENTION STR | | | | | | | |
| • EQUIP STORAGE PROVISIONS | | | | | | | |
| • TILT TABLE | | ● | | | | | |
| • PIDA | | | | | | | |
| • RMS | | | | | | | |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | | | | | |
| • MFR/RMS | | | | | | | |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ●—○ 2* | ●—○ 2* | ●—○ 2* | ●—○ 2* | ●—○ 2* | ●—○ 2* | ●—○ 2* |
| • PROX OPS MODULE – MANNED VERSION | | | | | | | |
| • PROX OPS MODULE – MTV ADAP'N | | | | | | | |
| • HPA | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ |
| • NON-CONTAM ACS | | | | | | | |
| • MTV | ● | ● | | ● | ● | | ● |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | | | | | | |
| • AFD C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● |

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| NOMINAL | | | | | | |
| • RETENTION STRUCTURE | ● ⊙ | ● ⊙ | ● ⊙ | ● ⊙ | | ● |
| • "SPECIAL" RETENTION STR | | | | | | |
| • EQUIP STORAGE PROVISIONS | | | | | | |
| • TILT TABLE | | | | | | |
| • PIDA | | | | | | |
| • RMS | | | | | | |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | | | | |
| • MFR/RMS | | | | | | |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ●—○ 2* | ●—○ 2* | ●—○ 2* | ●—○ 2* | ●—○ 2* | ●—○ 2* |
| • PROX OPS MODULE – MANNED VERSION | | | | | | |
| • PROX OPS MODULE – MTV ADAP'N | | | | | | |
| • HPA | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ | ●—○ |
| • NON-CONTAM ACS | | | | | | |
| • MTV | ● | ● | ● | ● | ● | ● |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | | | | | |
| • AFD C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● |

(IRAD)

CODE ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL ○○ / ●○ ONE UNIT *EVA VIA HANDRAILS OPTIONAL
○ 2 SECOND MMU/WRU REQD † APPENDIX B SCENARIO

R81-0181-046(T)

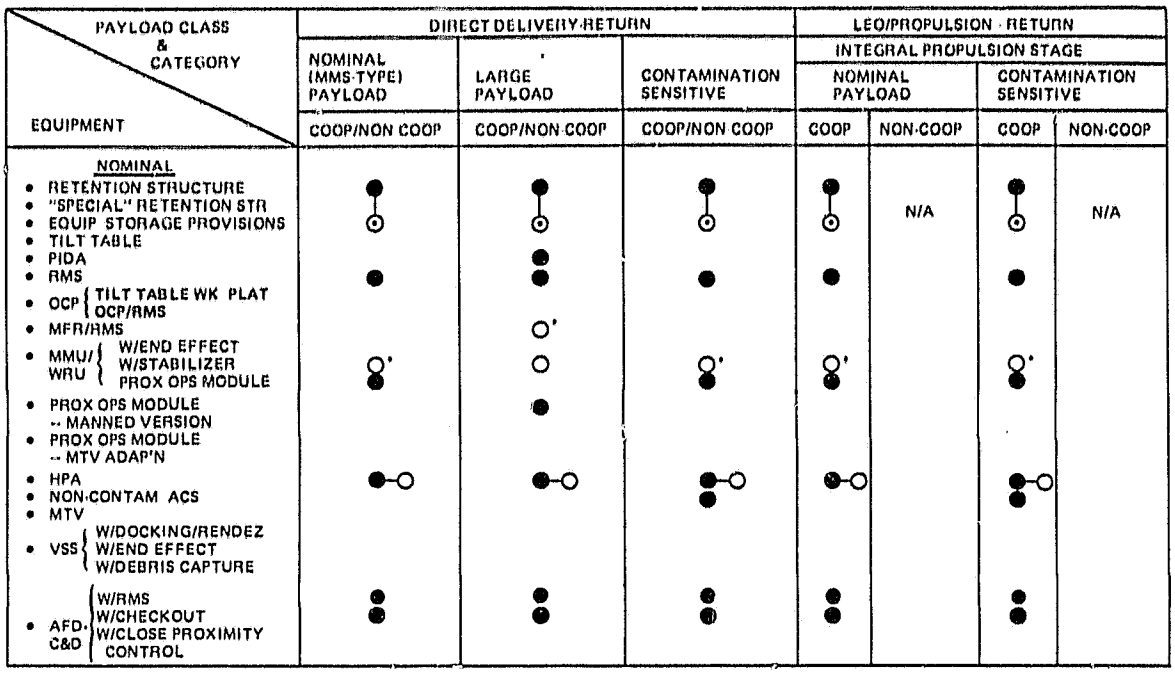
**Fig. 3.2-41 Earth Return – Equipment Utilization Summary – Alternate Scenario No. 1 – RMS/HPA Usage – RMS Inoperative**

nominal orbit to enable capture of the satellite/stage by the manned POM and retrieval by the RMS/Orbiter.

As shown in the Earth Return Scenarios matrix, two Level-1 sequences-of-events were prepared (ER-5, ER-6) to aid in surfacing the equipment usage. The overall equipment usage for the Alternate No. 2 revisit scenarios is shown in Fig. 3.2-42. The nominal and backup service equipment is shown for the five earth return scenarios in which manned retrieval of satellites at 1000 ft separation are applicable. Manned retrievals would be accomplished by Proximity Operations Modules in either of two variations: an "MMU/WRU adaptation" or by a "Manned Version." The distinction between the two is that the POM-MMU/WRU adaptation applies to masses in the range of MMS-type payloads (or smaller); for larger payloads (such as AXAF or Space Telescope), a larger POM-Manned version has been called for.

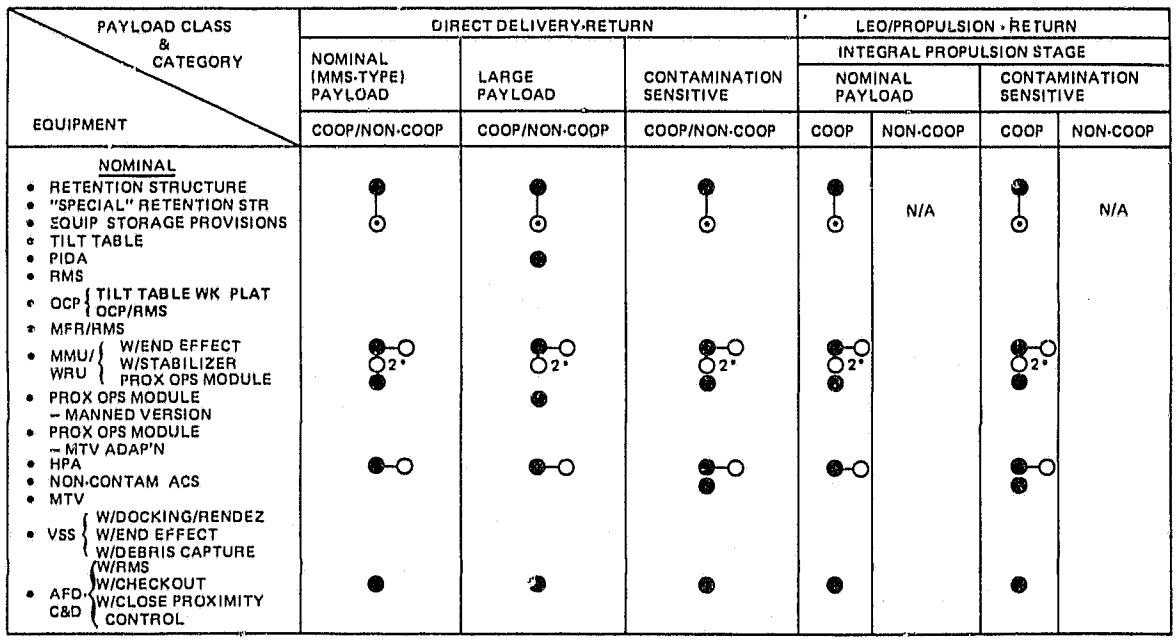
As shown in Fig. 3.2-42, the service equipment complements for these scenarios are similar, except for the contamination-sensitive payloads which call for a noncontaminating Orbiter ACS for the earth return mission and the use of the Payload Installation/Deployment Aid (PIDA) for large payloads. Exclusive of AFD Controls/Displays, between five and seven items of service equipment are needed to cover these earth return service scenarios.

Figure 3.2-43 presents the equipment complements for the same five Alternate No. 2 scenarios reflected in Fig. 3.2-42, but now with the RMS inoperative. Again, the MMU/WRU adaptations appear as the contingency elements for RMS inoperative situations. Exclusive of AFD Controls/Displays, five or six items of service equipment are needed to cover these earth return service scenarios.




R81-0181-047(T)

**Fig. 3.2-42 Earth Return — Equipment Utilization Summary — Alternate Scenario No. 2 — RMS/HPA Usage — Manned Retrieval of Satellites at 1000 Ft Separation**




R81-0181-048(T)

**Fig. 3.2-43 Earth Return — Equipment Utilization Summary, Alternate Scenario No. 2 — RMS/HPA Usage — Manned Retrieval of Satellites at 1000 Ft Separation — RMS Inoperativd**

### 3.2.3.5 Alternate Earth Return Scenarios No. 3 - RMS/HPA Usage - Unmanned Retrieval at 1000 ft Separation

The Alternate No. 3 series of scenarios referred to in the Earth Return Scenarios matrix (Ref: Fig. 3.2-32) represents scenarios where the Orbiter would rendezvous within 1000 ft of a payload. An unmanned Proximity Operations Module (POM) would then be deployed to retrieve and bring the payload to within RMS reach distance. The payload is then captured by the RMS and placed on the Handling & Positioning Aid (HPA) for final checkout/appendage or equipment removal, prior to RMS stowage of the payload in the Orbiter payload bay.

The scenarios apply to the Direct Delivery-Return, and LEO/Propulsion payload classes. (Again, only the cooperative payloads with integral propulsion are considered herein, since the balance of the LEO/Propulsion payload categories would be handled via Versatile Service Stage usage which were covered in Alternate Scenarios No. 1.) The satellite, with its integral stage, would return from its operational orbit to the Orbiter's orbit to enable capture of the satellite/stage by the unmanned POM and retrieval by the RMS/Orbiter.

As shown in the Earth Return Scenarios matrix, the ER-7 Level-1 sequence-of-events was prepared to aid in surfacing equipment usage. The overall equipment usage for the Alternate No. 3 scenarios is shown in Fig. 3.2-44. The nominal and backup service equipment is shown for the five earth return scenarios in which unmanned retrieval of satellites at 1000 ft separation are applicable. Retrievals are accomplished by a Proximity Operations Module-MTV adaptation capable of handling the spectrum of satellite masses projected in our Satellite and Services User Model (S/SUM). Service equipment complements are almost identical to the manned retrieval scenarios (Fig. 3.2-42), but with the addition of an Aft Flight Deck Control/Display for close proximity flight control (remote) of the POM by the Orbiter crew. Exclusive of AFD Controls/Displays, six or seven items of service equipment are needed to cover these earth return servicing scenarios.

Figure 3.2-45 presents the equipment needs for the same five Alternate No. 3 scenarios reflected in Fig. 3.2-44, but now with the RMS-inoperative. Again, the MMU/WRU adaptations appear as the contingency elements for RMS-inoperative situations. Exclusive of AFD Controls/Displays, between five and six items of service equipment are needed to cover these earth return servicing scenarios.

† (ER-7)

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON COOP | COOP/NON COOP | COOP/NON COOP | COOP | NON COOP | COOP | NON COOP |
| NOMINAL | | | | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● | N/A | ● | N/A |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ | | ⊙ | |
| • EQUIP STORAGE PROVISIONS | | | | | | | |
| • TILT TABLE | | ● | | | | | |
| • PIDA | | | | | | | |
| • RMS | ● | ● | ● | ● | | ● | |
| • OCP { TILT TABLE WK PLAT / OCP/RMS | | | | | | | |
| • MFR/RMS | ○' | ○' | ○' | ○' | | ○' | |
| • MMU/WRU { W/END EFFECT / W/STABILIZER / PROX OPS MODULE | ○' | | ○' | ○' | | ○' | |
| • PROX OPS MODULE –MANNED VERSION | | | | | | | |
| • PROX OPS MODULE –MTV ADAP'N | ● | ● | ● | ● | | ● | |
| • HPA | ●–○ | ●–○ | ●–○ | ●–○ | | ●–○ | |
| • NON-CONTAM ACS | | | ● | | | ● | |
| • MTV | | | | | | | |
| • VSS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE | | | | | | | |
| • AFD-C&D { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL | ● / ● / ● | ● / ● / ● | ● / ● / ● | ● / ● / ● | | ● / ● / ● | |

(IRAD) CODE: ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL ○○ ONE UNIT *EVA VIA HANDRAILS OPTIONAL
† APPENDIX B SCENARIO N/A = NOT APPLICABLE

R81-0181-049(T)

**Fig. 3.2-44 Earth Return – Equipment Utilization Summary – Alternate Scenario No. 3 – RMS/HPA Usage – Unmanned Retrieval of Satellites at 1000 Ft Separation**

† (ER-8)

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| NOMINAL | | | | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● | N/A | ● | N/A |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ | | ⊙ | |
| • EQUIP STORAGE PROVISIONS | | | | | | | |
| • TILT TABLE | | ● | | | | | |
| • PIDA | | | | | | | |
| • RMS | | | | | | | |
| • OCP { TILT TABLE WK PLAT / OCP/RMS | | | | | | | |
| • MFR/RMS | | | | | | | |
| • MMU/WRU { W/END EFFECT / W/STABILIZER / PROX OPS MODULE | ●–○ ○2' | ● ○ | ●–○ ○2' | ●–○ ○2' | | ●–○ ○2' | |
| • PROX OPS MODULE – MANNED VERSION | | | | | | | |
| • PROX OPS MODULE – MTV ADAP'N | ● | ● | ● | ● | | ● | |
| • HPA | ●–○ | ●–○ | ●–○ | ●–○ | | ●–○ | |
| • NON-CONTAM ACS | | | ● | | | ● | |
| • MTV | | | | | | | |
| • VSS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE | | | | | | | |
| • AFD-C&D { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL | ● / ● / ● | ● / ● / ● | ● / ● / ● | ● / ● / ● | | ● / ● / ● | |

(IRAD) CODE: ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL ○○ ONE UNIT *EVA VIA HANDRAILS OPTIONAL
○2 SECOND MMU/WRU REQ'D † APPENDIX B SCENARIO N/A = NOT APPLICABLE

R81-0181-050(T)

**Fig. 3.2-45 Earth Return – Equipment Utilization Summary – Alternate Scenario No. 3 – RMS/HPA Usage – Unmanned Retrieval of Satellites at 1000 Ft Separation**

### 3.2.3.6 Summary of Earth Return Service Equipment and Usage

Figure 3.2-46 consolidates the equipment utilization summaries that apply to the 98 scenarios considered in the Earth Return Scenarios matrix. A total of 19 service equipment needs (18 nominal, one optional) have been identified to cover the earth return scenarios in Fig. 3.2-32. This equipment would be carried in the satellite services inventory to cover both planned and contingency situations. The service equipment needs identified for the earth return service missions follow:

Nominal Equipment Needs

| | |
|---|---|
| (1) Retention Structure | Satellite retention for earth return would merely duplicate the form of retention used for initial launch in the Orbiter. |
| (2) Special Retention Structure | Earth return of satellites previously launched by unmanned launch vehicles will require unique retention structures duplicating the original launch vehicle's support interface. Special structures would also be required to support earth return of pieces or elements of satellite debris. |
| (3) Equipment Storage | Stowage of spacecraft elements, such as equipment or appendages, may be needed to enable the satellite's support in its retention structure (e.g., nonretractable appendages). In these cases, it would be expected that these stowage provisions will be provided in the basic retention structure for the satellite as part of "special hardware" for earth return. |
| (4) Remote Manipulator System (RMS) | The RMS retrieves payloads when within the reach-distance of the RMS arm and is used to place the payloads in their retention structures within the payload bay. The RMS is also used to deploy the Maneuverable Television to examine payloads before retrieval and supports EVA operations with the Manipulator Foot Restraint unit. |

98 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP | COOP | NON-COOP | COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) | ER-1 | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ER-2 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) | ● | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #1 (RMS/HPA USAGE) | ER-3 | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ER-4 | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | "CLN" VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #2 (RMS/HPA USAGE-MANNED RETRIEVAL AT 1000') | ER-5 | ER-6 | ● | ● | N/A | ● | N/A |
| • RMS INOPERATIVE | ● | ● | ● | ● | N/A | ● | N/A |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | VSS-CL | MD-VE | CL-VSS-CL |
| • ALTERNATE #3 (RMS/HPA USAGE-UNMANNED RETRIEVAL AT 1000') | ● | ● | ER-7 | ● | N/A | ● | N/A |
| • RMS INOPERATIVE | ● | ● | ER-8 | ● | N/A | ● | N/A |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | VSS-CL | UN-VE | CL-VSS-CL |

ER-1

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY-RETURN | | |
|---|---|---|---|
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP |
| NOMINAL | | | |
| • RETENTION STRUCTURE | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | ⊙ | ⊙ | ⊙ |
| • TILT TABLE | | | |
| • PIDA | | ● | |
| • RMS | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | |
| • MFR/RMS | ○* | ○* | ○* |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ○ | | ⊙ |
| • PROX OPS MODULE – MANNED VERSION | | | ⊙ |
| • PROX OPS MODULE – MTV ADAPTN | | | ⊙ |
| • HPA | | | |
| • NON-CONTAM ACS | | | ● |
| • MTV | ● | ● | |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | | |
| • AFD-C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● ● ● | ● ● ● | ● ● ● |

– RMS USAGE

| PAYLOAD CLASS & CATEGORY / SCENARIO | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) | ● | ● | ● | ● | ● | ● |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #1 (RMS/HPA USAGE) | ER-9 | ER-10 | ● | ● | ER-11 | ER-12 |
| • RMS INOPERATIVE | ● | ● | ● | ● | ● | ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #2 (RMS/HPA USAGE - MANNED RETRIEVAL AT 1000') | N/A | N/A | N/A | N/A | N/A | N/A |
| • RMS INOPERATIVE | N/A | N/A | N/A | N/A | N/A | N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #3 (RMS/HPA USAGE - UNMANNED RETRIEVAL AT 1000') | N/A | N/A | N/A | N/A | N/A | N/A |
| • RMS INOPERATIVE | N/A | N/A | N/A | N/A | N/A | N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | LEO/PROPULSION - RETURN | | | |
|---|---|---|---|---|
| | VERSATILE SERVICE STAG | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP | NON-COOP | COOP | NON-COOP |
| NOMINAL | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | ⊙ | ⊙ | ⊙ | ⊙ |
| • TILT TABLE | | | | |
| • PIDA | | | | |
| • RMS | ● | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | | |
| • MFR/RMS | ○* | ○* | ○* | ○* |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ○ | ○ | ○ | ○ |
| • PROX OPS MODULE – MANNED VERSION | | | | |
| • PROX OPS MODULE – MTV ADAPTN | | | | |
| • HPA | | | | |
| • NON-CONTAM ACS | | | | |
| • MTV | ● | ● | ● | ● |
| • VPS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | ● ● | ● ● | ● ● | ● ● |
| • AFD-C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● ● ● | ● ● ● | ● ● ● | ● ● ● |

NOTE: FOR NON-COOPERATIVE SATELLITES THAT ARE VSS-COMPATIBLE (CAPABLE OF DOCKING TO VSS) AND STS-COMPATIBLE (E.G. OUTFITTED WITH RMS GRAPPLE FITTING), IT IS ASSUMED THAT THE DEGREE OF SATELLITE INSTABILITY IS NOT THAT SEVERE AS TO PRECLUDE CAPTURE BY TECHNIQUES APPLICABLE TO COOPERATIVE SATELLITES
THE UNLIKELY SITUATION OF VERY HIGH TUMBLE RATES (E.G. ~ 10 RPM) WOULD BE COVERED BY THE DEBRIS RETRIEVAL/RETURN SCENARIOS, AS WOULD APPLY TO SATELLITES TO BE RETRIEVED/RETURNED WHICH ARE NOT STS-COMPATIBLE (E.G. OAO)

CODE: OR-CL = ORBITER CLOSES; VSS-CL = VSS CLOSES; CL-VSS-CL = CLEAN VSS CLOSES; CL-VE = CLEAN VEHICLE CLOSES; MD-VE = MANNED VEHICLE CLOSES; UN-VE = UNMANNED VEHICLE CLOSES

R81-0181-037(T)

R81-0181-038(T)

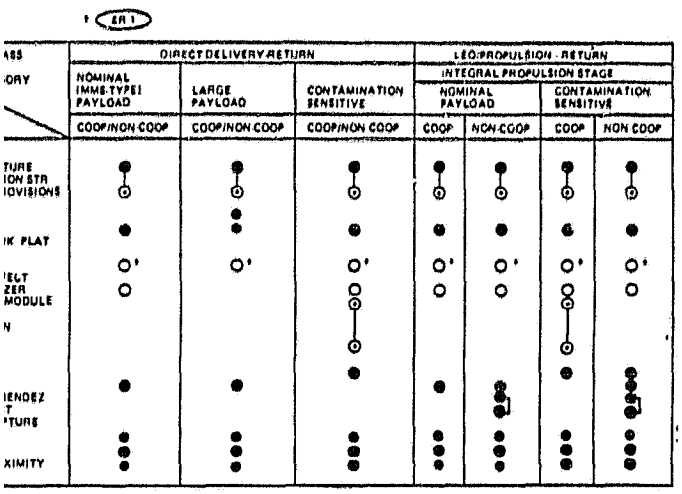
EARTH RETURN - SERVICING
SCENARIOS MATRIX

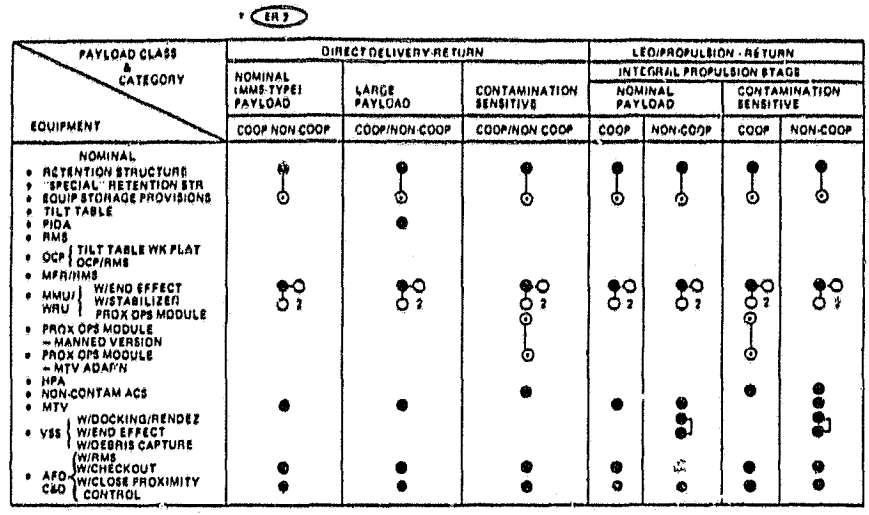
IRAD

R81-0181-051(",

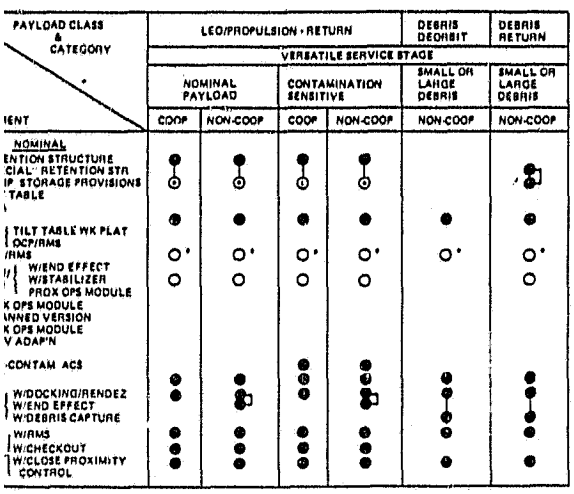
FOLDOUT FRAME

## NOMINAL SCENARIO NO. 1

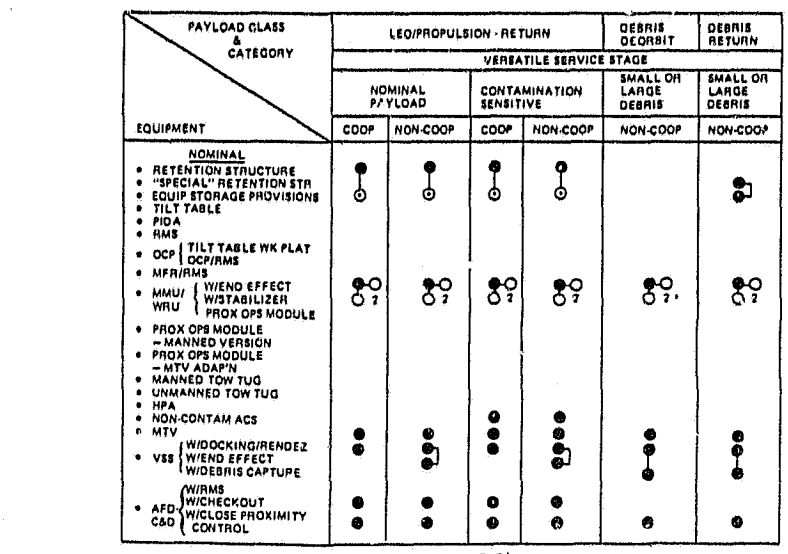



– RMS USAGE




RMS INOPERATIVE




CODE: ● PRIME USAGE ○ BACKUP ⊙ OPTIONAL ○○/●● ONE UNIT *EVA VIA HANDRAILS OPTIONAL
○² SECOND MMU/WRU REQ'D † APPENDIX B SCENARIO

R81-0181-039(T)

Fig. 3.2-46(a) Service Equipment Utilization for Ear
Return Servicing Scenarios: Nominal
Scenario No. 1

FOLDOUT FRAME 2

98 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY-RETURN | | | LEO/PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON COOP | COOP/NON-COOP | COOP/NON COOP | COOP | NON-COOP | COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) • RMS INOPERATIVE | ER-1 / ER-2 | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) • RMS INOPERATIVE | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #1 (RMS/HPA USAGE) • RMS INOPERATIVE | ER-3 / ER-4 | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #2 (RMS/HPA USAGE-MANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | ER-5 / ● | ER-6 / ● | ● / ● | ● / ● | N/A / N/A | ● / ● | N/A / N/A |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | VSS CL | MD-VE | CL-VSS-CL |
| • ALTERNATE #3 (RMS/HPA USAGE-UNMANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | ● / ● | ● / ● | ER-7 / ER-8 | ● / ● | N/A / N/A | ● / ● | N/A / N/A |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | VSS-CL | UN-VE | CL-VSS-CL |

| PAYLOAD CLASS & CATEGORY / SCENARIO | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) • RMS INOPERATIVE | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) • RMS INOPERATIVE | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #1 (RMS/HPA USAGE) • RMS INOPERATIVE | ER-9 / ● | ER-10 / ● | ● / ● | ● / ● | ER-11 / ● | ER-12 / ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #2 (RMS/HPA USAGE - MANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #3 (RMS/HPA USAGE UNMANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |

NOTE - FOR NON-COOPERATIVE SATELLITES THAT ARE VSS-COMPATIBLE (CAPABLE OF DOCKING TO VSS) AND STS-COMPATIBLE (E.G. OUTFITTED WITH RMS GRAPPLE FITTING), IT IS ASSUMED THAT THE DEGREE OF SATELLITE INSTABILITY IS NOT THAT SEVERE AS TO PRECLUDE CAPTURE BY TECHNIQUES APPLICABLE TO COOPERATIVE SATELLITES
- THE UNLIKELY SITUATION OF VERY HIGH TUMBLE RATES (E.G. ~ 10 RPM) WOULD BE COVERED BY THE DEBRIS RETRIEVAL/RETURN SCENARIOS, AS WOULD APPLY TO SATELLITES TO BE RETRIEVED/RETURNED WHICH ARE NOT STS-COMPATIBLE (E.G. OAO)

CODE: OR-CL = ORBITER CLOSES; VSS-CL = VSS CLOSES; CL-VSS-CL = CLEAN VSS CLOSES; CL-VE = CLEAN VEHICLE CLOSES; MD-VE = MANNED VEHICLE CLOSES; UN-VE = UNMANNED VEHICLE CLOSES

R81-0181-037(T)

EARTH RETURN - SERVICING SCENARIOS MATRIX

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY-RETURN | | |
|---|---|---|---|
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMI SENSITIV |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NO |
| NOMINAL | | | |
| • RETENTION STRUCTURE | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | ⊙ | ⊙ | ⊙ |
| • TILT TABLE | ● | ● | ● |
| • PIDA | ● | ● | ● |
| • RMS | ● | ● | ● |
| • OCP { TILT TABLE W/K PLAT / OCP/RMS | ● | ● | ● |
| • MFR/RMS | ○* | ○* | ○ |
| • MMU/WRU { W/END EFFECT / W/STABILIZER PROX OPS MODULE | ○* | ○* | ○ |
| • PROX OPS MODULE -MANNED VERSION | | | ⊙ |
| • PROX OPS MODULE -MTV ADAP'N | | | ⊙ |
| • HPA | | | |
| • NON-CONTAM ACS | | | ● |
| • MTV | ● | ● | |
| • VSS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE | | | |
| • AFD-C&D { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL | ● / ● / ● | ● / ● / ● | ● / ● / ● |

— RMS/HPA USAGE

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | LEO/PROPULSION - RET | | |
|---|---|---|---|
| | VERSAT | | |
| | NOMINAL PAYLOAD | | CONTA SENSITI |
| | COOP | NON-COOP | COOP |
| NOMINAL | | | |
| • RETENTION STRUCTURE | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | ⊙ | ⊙ | ⊙ |
| • TILT TABLE | ● | ● | ● |
| • PIDA | ● | ● | ● |
| • RMS | ● | ● | ● |
| • OCP { TILT TABLE W/K PLAT / OCP/RMS | ● | ● | ● |
| • MFR/RMS | ○* | ○* | ○* |
| • MMU/WRU { W/END EFFECT / W/STABILIZER PROX OPS MODULE | ○* | ○* | ○* |
| • PROX OPS MODULE -MANNED VERSION | | | |
| • PROX OPS MODULE -MTV ADAP'N | | | |
| • HPA | | | |
| • NON-CONTAM ACS | | | ● |
| • MTV | ● | ● | ● |
| • VSS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE | ● | ● | ● |
| • AFD-C&D { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL | ● / ● / ● | ● / ● / ● | ● / ● / ● |

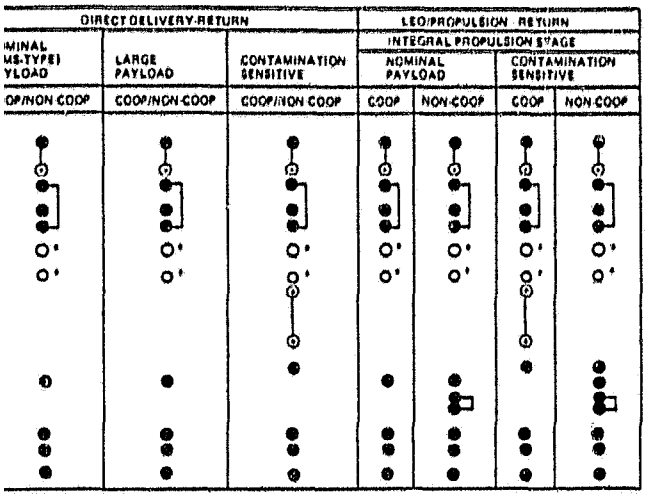
R81-0181-040(T)

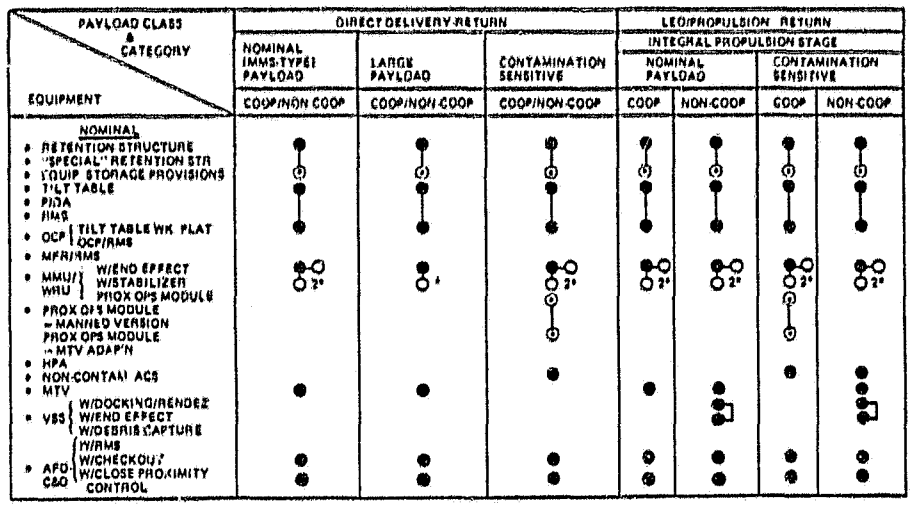
IRAD

R81-0181-052(T)

FOLDOUT FRAME

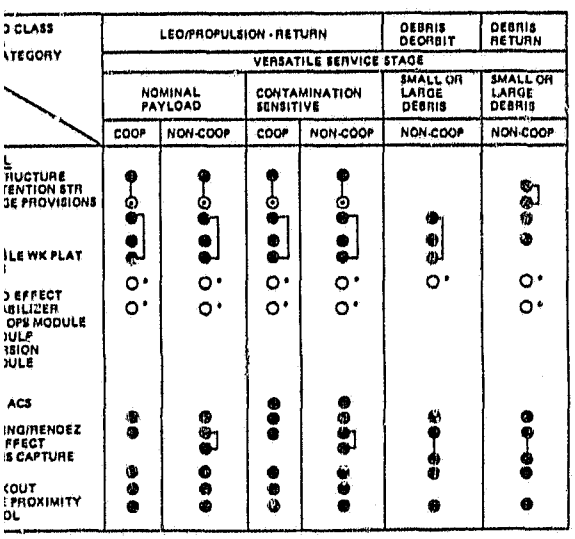
## NOMINAL SCENARIO NO. 2

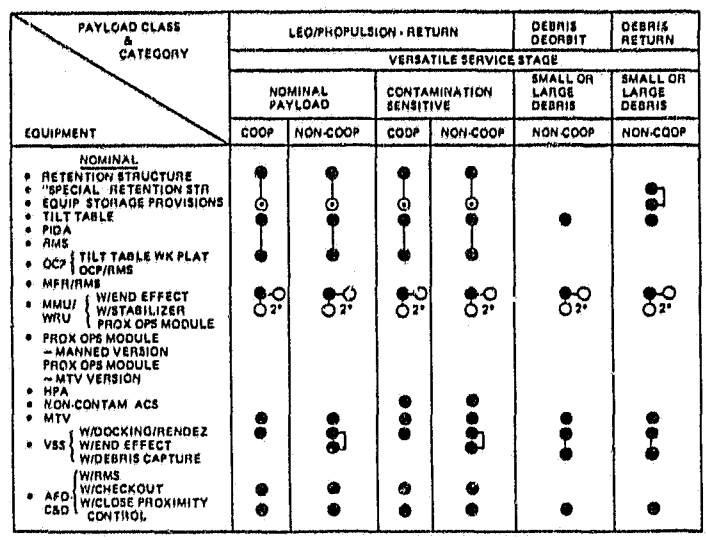



– RMS/HPA USAGE

– RMS/HPA USAGE
– RMS INOPERATIVE




R81-0161-041(T)

FOLDOUT FRAME 2

Fig. 3.2-31(b) Service Equipment Utilization for Revisit Servicing Scenarios: Nominal Scenario No. 2

98 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY RETURN | | | LEO PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON COOP | COOP NON COOP | COOP NON COOP | COOP | NON COOP | COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) • RMS INOPERATIVE | ER 1 / ER 2 | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | ORB CL | VSS CL | CL VE | CL VSS CL |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) • RMS INOPERATIVE | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | ORB CL | VSS CL | CL VE | CL VSS CL |
| • ALTERNATE #1 (RMS/HPA USAGE) • RMS INOPERATIVE | ER 3 / ER 4 | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | ORB CL | VSS CL | CL VE | CL VSS CL |
| • ALTERNATE #2 (RMS/HPA USAGE MANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | ER 9 / ● | ER 9 / ● | ● / ● | ● / ● | N/A / N/A | ● / ● | N/A / N/A |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | VSS CL | MD-VE | CL-VSS CL |
| • ALTERNATE #3 (RMS/HPA USAGE UNMANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | ● / ● | ● / ● | ER 7 / ER 8 | ● / ● | N/A / N/A | ● / ● | N/A / N/A |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | VSS CL | UN VE | CL-VSS-CL |

ER 3

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY RETURN | | |
|---|---|---|---|
| | NOMINAL (MMS TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE |
| | COOP/NON COOP | COOP/NON COOP | COOP/NON COOP |
| NOMINAL | | | |
| • RETENTION STRUCTURE | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | ⊙ | ⊙ | ⊙ |
| • TILT TABLE | | | |
| • PIDA | | ● | |
| • RMS | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT / OCP/RMS } | | | |
| • MFR/RMS | ○' | ○' | ○' |
| • MMU/WRU { W/END EFFECT / W/STABILIZER / PROX OPS MODULE } | ○' | | ○' ⊗ |
| • PROX OPS MODULE = MANNED VERSION | | | ⊗ |
| • PROX OPS MODULE = MTV ADAPTN | | | ⊗ |
| • HPA | ●—○ | ●—○ | ●—○ |
| • NON-CONTAM ACS | | | ● |
| • MTV | ● | ● | |
| • VSS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE } | | | |
| • AFD/CAD { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL } | ● ● ● | ● ● ● | ● ● ● |

— RMS/HPA USAGE

| PAYLOAD CLASS & CATEGORY / SCENARIO | LEO/PROPULSION - RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) • RMS INOPERATIVE | ● ● | ● ● | ● ● | ● ● | ● ● | ● ● |
| CLOSE PROXIMITY OPS | CLEAN VSS CLOSES | | | | | |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) • RMS INOPERATIVE | ● ● | ⊙ ● | ● ● | ● ● | ● ● | ⊙ ● |
| CLOSE PROXIMITY OPS | CLEAN VSS CLOSES | | | | | |
| • ALTERNATE #1 (RMS/HPA USAGE) • RMS INOPERATIVE | ER 9 / ● | ER 10 / ● | ● ● | ● ● | ER 11 / ● | ER 12 / ● |
| CLOSE PROXIMITY OPS | CLEAN VSS CLOSES | | | | | |
| • ALTERNATE #2 (RMS/HPA USAGE MANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A |
| CLOSE PROXIMITY OPS | CLEAN VSS CLOSES | | | | | |
| • ALTERNATE #3 (RMS/HPA USAGE - UNMANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A |
| CLOSE PROXIMITY OPS | CLEAN VSS CLOSES | | | | | |

NOTE FOR NON-COOPERATIVE SATELLITES THAT ARE VSS COMPATIBLE (CAPABLE OF DOCKING TO VSS) AND STS-COMPATIBLE (E.G. OUTFITTED WITH RMS GRAPPLE FITTING), IT IS ASSUMED THAT THE DEGREE OF SATELLITE INSTABILITY IS NOT THAT SEVERE AS TO PRECLUDE CAPTURE BY TECHNIQUES APPLICABLE TO COOPERATIVE SATELLITES. THE UNLIKELY SITUATION OF VERY HIGH TUMBLE RATES (E.G. > 10 RPM) WOULD BE COVERED BY THE DEBRIS RETRIEVAL/RETURN SCENARIO, AS WOULD APPLY TO SATELLITES TO BE RETRIEVED/RETURNED WHICH ARE NOT STS-COMPATIBLE (E.G. OAO).

CODE: OR-CL = ORBITER CLOSES; VSS-CL = VSS CLOSES; CL-VSS-CL = CLEAN VSS CLOSES; CL-VE = CLEAN VEHICLE CLOSES; MD-VE = MANNED VEHICLE CLOSES; UN-VE = UNMANNED VEHICLE CLOSES

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EARTH RETURN - SERVICING SCENARIOS MATRIX

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| PAYLOAD CLASS & CATEGORY / EQUIPMENT | LEO/PROPULSION - RETURN | | | |
|---|---|---|---|---|
| | VERSATILE SER | | | |
| | NOMINAL PAYLOAD | | CONTAMINATI SENSITIVE | |
| | COOP | NON-COOP | COOP | NON-C |
| NOMINAL | | | | |
| • RETENTION STRUCTURE | ● | ● | ● | ● |
| • "SPECIAL" RETENTION STR | ⊙ | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | ⊙ | ⊙ | ⊙ | ⊙ |
| • TILT TABLE | | | | |
| • PIDA | | | | |
| • RMS | ● | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT / OCP/RMS } | | | | |
| • MFR/RMS | ○' | ○' | ○' | ○ |
| • MMU/WRU { W/END EFFECT / W/STABILIZER / PROX OPS MODULE } | ○' | ○' | ○' | ○ |
| • PROX OPS MODULE = MANNED VERSION | | | | |
| • PROX OPS MODULE = MTV ADAPTN | | | | |
| • HPA | ●—○ | ●—○ | ●—○ | ● |
| • NON-CONTAM ACS | | | | |
| • MTV | ● | ● | | |
| • VSS { W/DOCKING/RENDEZ / W/END EFFECT / W/DEBRIS CAPTURE } | | | | |
| • AFD/CAD { W/RMS / W/CHECKOUT / W/CLOSE PROXIMITY CONTROL } | ● ● ● | ● ● ● | ● ● ● | ● ● ● |

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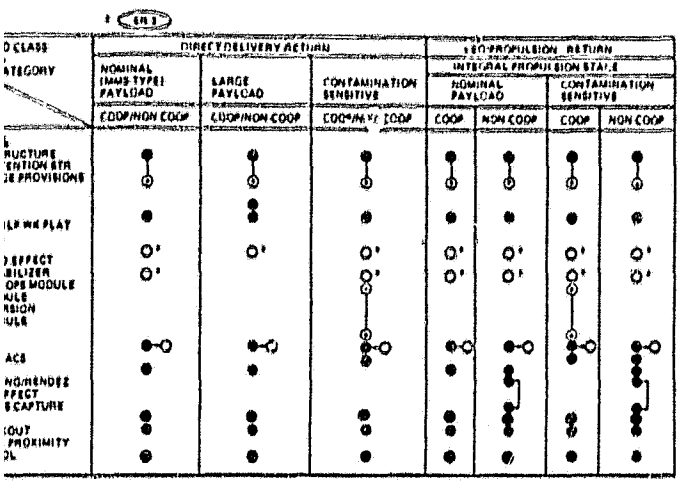
IRAD

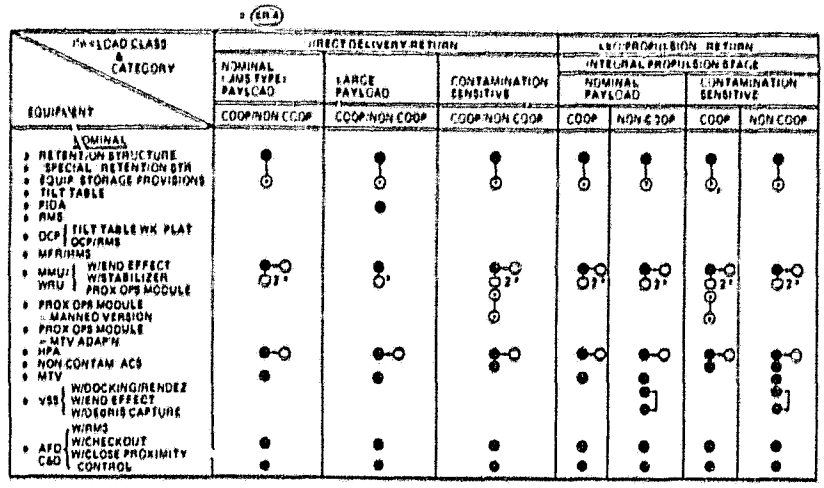
R81-0181-053(T)

FOLDOUT FRAME

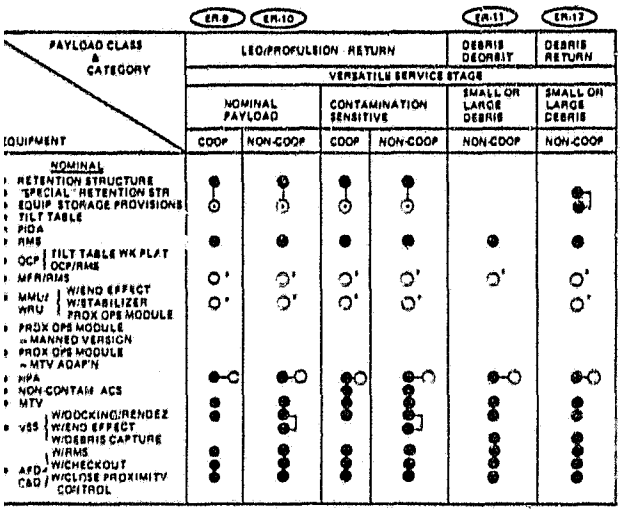
## ALTERNATE SCENARIO NO. 1



– RMS/HPA USAGE



– RMS/HPA USAGE
– RMS INOPERATIVE



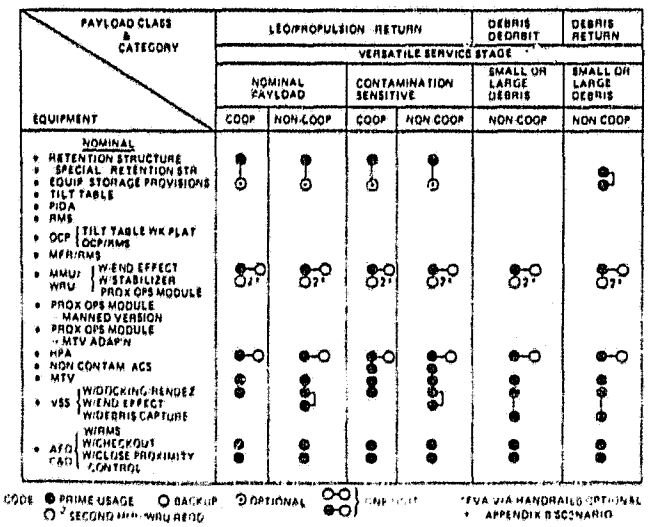


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Fig. 3.2-46(c) Service Equipment Utilization for Earth Return Servicing Scenarios: Alternate Scenario No. 1

FOLDOUT FRAME

98 SCENARIOS

| PAYLOAD CLASS & CATEGORY / SCENARIO | DIRECT DELIVERY RETURN | | | LEO/PROPULSION RETURN | | | |
|---|---|---|---|---|---|---|---|
| | | | | INTEGRAL PROPULSION STAGE | | | |
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | |
| | COOP/NON COOP | COOP/NON-COOP | COOP/NON COOP | COOP | NON-COOP | COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) • RMS INOPERATIVE | ER-1 / ER-2 | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) • RMS INOPERATIVE | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #1 (RMS/HPA USAGE) • RMS INOPERATIVE | ER-3 / ER-4 | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | ORBITER CLOSES | | CLN VEH CLOSES | OR-CL | VSS-CL | CL-VE | CL-VSS-CL |
| • ALTERNATE #2 (RMS/HPA USAGE-MANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | ER-5 / ● | ER-6 / ● | ● / ● | ● / ● | N/A / N/A | ● / ● | N/A / N/A |
| CLOSE PROXIMITY OPS | MANNED VEHICLE CLOSES | | | | VSS-CL | MD-VE | CL-VSS-CL |
| • ALTERNATE #3 (RMS/HPA USAGE-UNMANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | ● / ● | ● / ● | ER-7 / ER-8 | ● / ● | N/A / N/A | ● / ● | N/A / N/A |
| CLOSE PROXIMITY OPS | UNMANNED VEHICLE CLOSES | | | | VSS-CL | UN-VE | CL-VSS-CL |

| PAYLOAD CLASS & CATEGORY / SCENARIO | LEO/PROPULSION RETURN | | | | DEBRIS DEORBIT | DEBRIS RETURN |
|---|---|---|---|---|---|---|
| | VERSATILE SERVICE STAGE | | | | | |
| | NOMINAL PAYLOAD | | CONTAMINATION SENSITIVE | | SMALL OR LARGE DEBRIS | SMALL OR LARGE DEBRIS |
| | COOP | NON-COOP | COOP | NON-COOP | NON-COOP | NON-COOP |
| • NOMINAL #1 (RMS USAGE) • RMS INOPERATIVE | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • NOMINAL #2 (RMS/TILT TABLE USAGE) • RMS INOPERATIVE | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● | ● / ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #1 (RMS/HPA USAGE) • RMS INOPERATIVE | ER-9 / ● | ER-10 / ● | ● / ● | ● / ● | ER-11 / ● | ER-12 / ● |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #2 (RMS/HPA USAGE - MANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |
| • ALTERNATE #3 (RMS/HPA USAGE UNMANNED RETRIEVAL AT 1000') • RMS INOPERATIVE | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A | N/A / N/A |
| CLOSE PROXIMITY OPS | "CLEAN" VSS CLOSES | | | | | |

NOTE: FOR NON-COOPERATIVE SATELLITES THAT ARE VSS-COMPATIBLE (CAPABLE OF DOCKING TO VSS) AND STS-COMPATIBLE (E.G. OUTFITTED WITH RMS GRAPPLE FITTING), IT IS ASSUMED THAT THE DEGREE OF SATELLITE INSTABILITY IS NOT THAT SEVERE AS TO PRECLUDE CAPTURE BY TECHNIQUES APPLICABLE TO COOPERATIVE SATELLITES
- THE UNLIKELY SITUATION OF VERY HIGH TUMBLE RATES (E.G. ~ 10 RPM) WOULD BE COVERED BY THE DEBRIS RETRIEVAL/RETURN SCENARIO, AS WOULD APPLY TO SATELLITES TO BE RETRIEVED/RETURNED WHICH ARE NOT STS-COMPATIBLE (E.G. GAO)

CODE: OR-CL = ORBITER CLOSES; VSS-CL = VSS CLOSES; CL-VSS-CL = CLEAN VSS CLOSES; CL-VE = CLEAN VEHICLE CLOSES; MD-VE = MANNED VEHICLE CLOSES; UN-VE = UNMANNED VEHICLE CLOSES

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EARTH RETURN – SERVICING
SCENARIOS MATRIX

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C-2



## ALTERNATE SCENARIO N

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY RETURN | | |
|---|---|---|---|
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE |
| | COOP/NON COOP | COOP/NON COOP | COOP/NON COOP |
| NOMINAL | | | |
| • RETENTION STRUCTURE | ● | ● | ● |
| • 'SPECIAL' RETENTION STR | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | | | |
| • TILT TABLE | | ● | |
| • PIDA | | ● | |
| • RMS | ● | ● | ● |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | |
| • MFR/RMS | | ○' | |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ○' | ○ | ○' |
| • PROX OPS MODULE – MANNED VERSION | | ● | |
| • PROX OPS MODULE – MTV ADAP'N | | | |
| • HPA | ●—○ | ●—○ | ●—○ |
| • NON-CONTAM ACS | | | ● |
| • MTV | | | |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | | |
| • AFD C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● | ● | ● |

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– RMS/HPA USAGE
– MANNED RETRIEVAL OF SA

| PAYLOAD CLASS & CATEGORY / EQUIPMENT | DIRECT DELIVERY RETURN | | |
|---|---|---|---|
| | NOMINAL (MMS-TYPE) PAYLOAD | LARGE PAYLOAD | CONTAMINATION SENSITIVE |
| | COOP/NON-COOP | COOP/NON-COOP | COOP/NON-COOP |
| NOMINAL | | | |
| • RETENTION STRUCTURE | ● | ● | ● |
| • 'SPECIAL' RETENTION STR | ⊙ | ⊙ | ⊙ |
| • EQUIP STORAGE PROVISIONS | | | |
| • TILT TABLE | | ● | |
| • PIDA | | | |
| • RMS | | | |
| • OCP { TILT TABLE WK PLAT; OCP/RMS } | | | |
| • MFR/RMS | | | |
| • MMU/WRU { W/END EFFECT; W/STABILIZER; PROX OPS MODULE } | ●—○ 2' ● | ●—○ 2' ● | ●—○ 2' ● |
| • PROX OPS MODULE – MANNED VERSION | | ● | |
| • PROX OPS MODULE – MTV ADAP'N | | | |
| • HPA | ●—○ | ●—○ | ●—○ |
| • NON-CONTAM ACS | | | ● |
| • MTV | | | |
| • VSS { W/DOCKING/RENDEZ; W/END EFFECT; W/DEBRIS CAPTURE } | | | |
| • AFD C&D { W/RMS; W/CHECKOUT; W/CLOSE PROXIMITY CONTROL } | ● | ● | ● |

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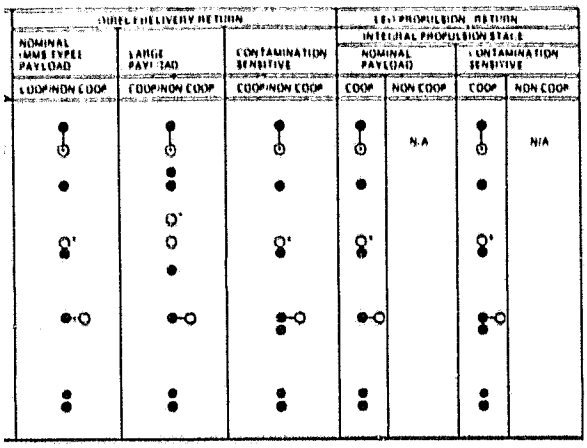
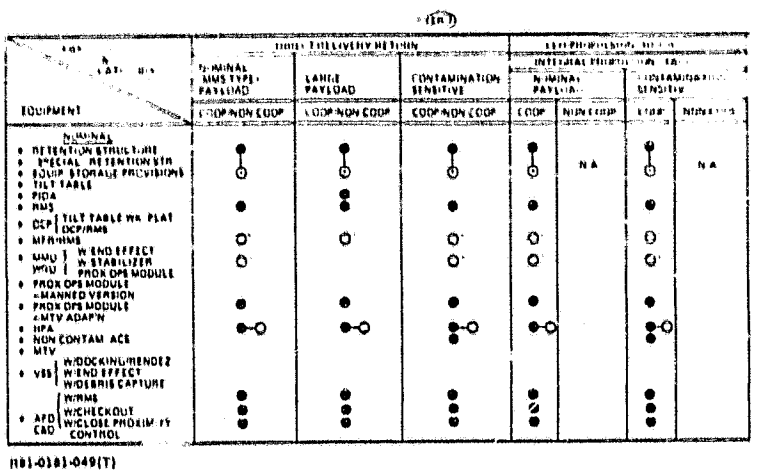
– RMS/HPA USAGE
– MANNED RETRIEVAL OF S
– RMS INOPERATIVE

## ALTERNATE SCENARIO NO. 2




- RMS/HPA USAGE
- MANNED RETRIEVAL OF SATELLITES

## ALTERNATE SCENARIO NO. 3

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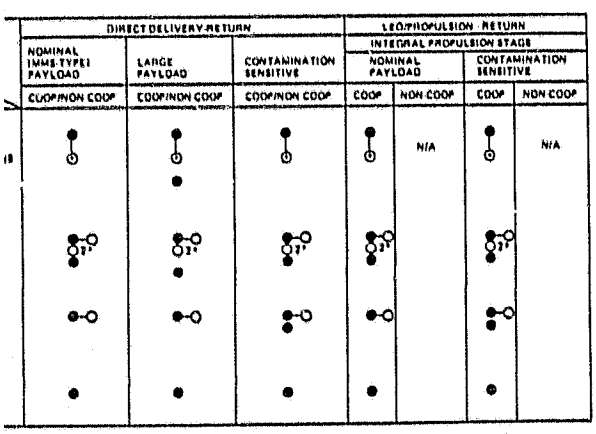
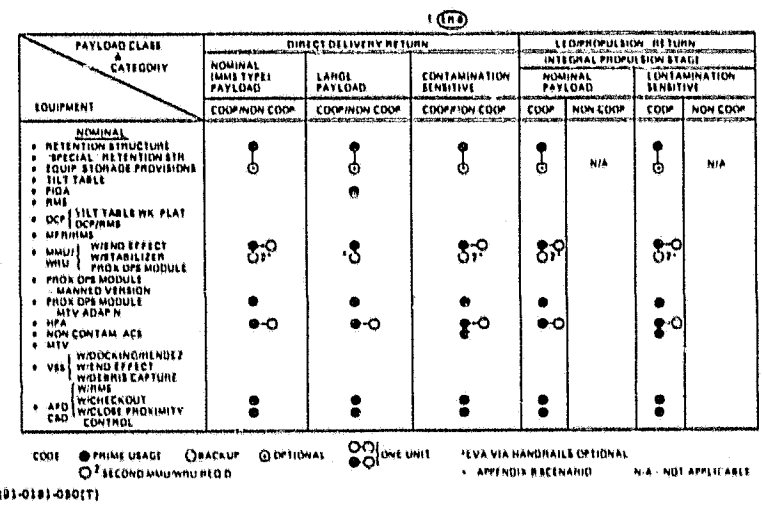
- RMS/HPA USAGE
- UNMANNED RETRIEVAL OF SATELLITES




- RMS/HPA USAGE
- MANNED RETRIEVAL OF SATELLITES
- RMS INOPERATIVE

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- RMS/HPA USAGE
- UNMANNED RETRIEVAL OF SATELLITES
- RMS INOPERATIVE

Fig. 3.2-46(d) Service Equipment Utilization for Earth Return Servicing Scenarios: Alternate Scenario No. 2; Alternate Scenario No. 3

| | |
|---|---|
| (5) Tilt Table and Open Cherry Picker (OCP) Tilt Table Work Platform | For those satellites that utilize the FSS Cradle A' Tilt Table (or equivalent) for initial launch, and the Tilt Table/OCP Work Platform for on-orbit servicing, the same hardware could be provided to enable checkout/equipment or appendage removal prior to earth return. Additionally, the Tilt Table could also serve as an element of the satellite's retention structure. |
| (6) Manipulator Foot Restraint (MFR)/RMS | The MFR/RMS serves as a backup for potential hangups of mechanical devices in the payload bay for earth return missions and hangup situations associated with satellite appendages. |
| (7) Maneuverable Television (MTV) | As in the revisit-servicing missions, the MTV is used to remotely examine all satellites prior to Orbiter retrieval and can be deployed to view and record Versatile Service Stage firings. The system is flown by the Orbiter crew from the Aft Flight Deck. |
| (8) Payload Installation and Deployment Aid (PIDA) | Enables re-installation into the payload bay of very large size/mass payloads (e.g., 15 ft diameter and 65,000 lb) that are "tight" in terms of the 3.0 inch Orbiter clearance envelope. |
| (9) Handling and Positioning Aid (HPA) | The HPA, with its standardized berthing and umbilical interface, supports the deployment of the Versatile Service Stage, and also enables checkout/equipment or appendage removal from a satellite prior to earth return. |
| (10) Noncontaminating Attitude Control System (ACS) | Orbiter retrieval of contamination-sensitive satellites could be supported by providing a noncontaminating ACS package in the payload bay or, alternatively, by placing the Orbiter, |

| | |
|---|---|
| | into a free-drift mode during satellite capture operations. |
| (11-13) Aft Flight Deck Controls & Displays (AFD-C&D):<br>• RMS Control Panel<br>• Satellite C/O Panel<br>• Close Proximity Ops Panel | Controls and displays will be provided in the AFD for control of the RMS, for checkout of the satellite prior to earth return, and for close proximity flight control of the MTV, Versatile Service Stage, and the unmanned Proximity Operations Module. |
| (14) Manned Maneuvering Unit/ Work Restraint Unit (MMU/WRU) | Adaptations of the WRU in conjunction with the MMU again serve as the backup for RMS inoperative situations for earth return service missions. Two "kit" adaptations apply for these missions: (1) an RMS snare end-effector to enable payload retrieval, and (2) a stabilizer to allow for manual assist (by an astronaut) of mechanical hangups in the payload bay area. |
| (15) Proximity Ops Module (POM)-MMU/WRU Adaptation<br>(16) Proximity Ops Module (POM)-Manned Version<br>(17) Proximity Ops Module (POM)-MTV Adaptation | Retrieval of spacecraft within 1000 ft of the Orbiter would be accomplished by Proximity Operations Modules in the same manner as previously described for the revisit-service missions. |
| (18) Versatile Service Stage (VSS)<br>• Rendezvous/Retrieval Capability<br>• Non-cooperative Satellite Retrieval Capability<br>• Debris Capture Capability | The VSS is again used to retrieve satellites from higher energy orbits not directly accessible by the Orbiter. In addition to the capabilities needed for revisit-service missions, the earth return service missions call for debris retrieval and controlled debris de-orbit. The VSS would be adapted with a special front-end "kit" designed to capture uncooperative/unstable spacecraft. Following capture, the VSS could impart a $\Delta V$ to effect controlled reentry of the debris, or return and rendezvous with the Orbiter. |

Optional Equipment

(19) Lighting Enhancement — Supplementary lighting or enhanced viewing capabilities are provided for nominal and backup EVA activities associated with earth return service missions.

### 3.2.4 Orbital Storage

The orbital storage mode provides the satellite user with the option to leave the spacecraft on-orbit for subsequent revisit/repair in the event of a malfunction detected prior to deployment that would categorize the satellite non-operational. Orbital storage negates the need for carrying backup spares, etc. (incurring added user charges), and eliminates the necessity for returning a satellite to earth for repair and subsequent relaunch (also additional user charges).

Scenarios for four orbital storage options have been developed (Ref: Fig. 3.2-47) and are provided in Appendix B. The scenarios indicate that the operations involved, to completely envelop a satellite with an enclosure, are slightly different depending upon whether a satellite is greater or less than 15 ft long.

| PAYLOAD CLASS & CATEGORY / SCENARIO | ORBITAL STORAGE OPTION | |
|---|---|---|
| | SAT. $\leq$ 15 ft LONG | SAT. $>$ 15 ft LONG |
| • NOMINAL (RMS/HPA USAGE) | OS-1 | OS-3 |
| • RMS INOPERATIVE | OS-2 | OS-4 |

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Fig. 3.2-47 Orbital Storage Options

Satellites longer than 15 ft must be lifted off the HPA and supported by the HPA work platform while the enclosure is fitted over the satellite. To effect this operation the HPA work platform would be adapted with an RMS end-effector to enable the platform to support the satellite via its grapple fixture.

In contrast, satellites less than 15 ft long can be fitted with the enclosure while remaining attached to the HPA. The scenarios in Appendix B contain additional details relating to the on-orbit operations associated with effecting the orbital storage mode.

## 3.3 SERVICE EQUIPMENT - SUMMARY

Figure 3.3-1 summarizes the service equipment needs identified for the major mission events: initial launch, revisit, and earth return, as reflected in the 180 on-orbit operations scenarios considered herein. The service equipment needs and their related equipment categories are:

| EQUIPMENT CATEGORY | IDENTIFIED SERVICE EQUIPMENT NEEDS |
|---|---|
| Support Structure | 2 |
| On-Orbit Equipment | 15 |
| Free-Flight Systems | 10 |
| Optional Equipment | 4 |
| Advanced Capabilities | 2 |
| Tools | 1 |
| Total | 34 |

Primary (solid bullet) and backup equipment (open bullet) is shown; bullets with connecting lines refer to equipment needs that could be satisfied by single units of service hardware. Clearly, many service equipment needs appear on more than one major mission event.

Figure 3.3-2 indicates the status of the equipment identified and notes equipment which exists, is under development, or has been newly identified. Each item of hardware under development and the new equipment identified is referenced to the service equipment requirements sheets that follow.

| EQUIPMENT CATEGORY | MISSION EVENT | | |
|---|---|---|---|
| | INITIAL LAUNCH | REVISIT | EARTH RETURN |
| **SUPPORT STRUCTURE** | | | |
| • RETENTION STRUCTURE | ● | | ● |
| • SPECIAL RETENTION STRUCTURE | | | ● |
| **ON-ORBIT EQUIPMENT** | | | |
| • REMOTE MANIPULATOR SYSTEM (RMS) | ● | ● | ● |
| • TILT TABLE (FSS, IUS, PAM-A) | ● | ● | ● |
| • OPEN CHERRY PICKER (OCP) — TILT TABLE WORK PLATFORM | | ● | ● |
| • OPEN CHERRY PICKER (OCP) — OCP/RMS | | ● | |
| • MANIPULATOR FOOT RESTRAINT/RMS | ○ | ○ | ○ |
| • PAYLOAD INSTALLATION/DEPLOYMENT AID (PIDA) | ● | | ● |
| • HANDLING & POSITIONING AID (HPA) | ● | ● | ● |
| • SPIN TABLE (PAM-A, PAM-D) | ● | | |
| • EQUIPMENT STORAGE — ON-ORBIT SUPPORT | | ● | |
| • EQUIPMENT STORAGE — EARTH RETURN | | | ● |
| • FLUID TRANSFER SYSTEM | | ● | |
| • NON-CONTAMINATING ACS | | ● | ● |
| • AFD-CONTR/DISPL — W/RMS CONTROL | ● | ● | ● |
| • AFD-CONTR/DISPL — W/STD SATELL C/O | ● | ● | ● |
| • AFD-CONTR/DISPL — W/CLOSE PROX CONTR | ● | ● | ● |
| **FREE FLIGHT SYSTEMS** | | | |
| • MANEUVERABLE TELEVISION (MTV) | ● | ● | ● |
| • PROXIMITY OPS MODULE - MTV ADAPTATION | | ● | ● |
| • PROXIMITY OPS MODULE - MANNED VERSION | | ● | ● |
| • MAN, MANEUV UNIT/WK RESTRAINT UNIT (MMU/WRU) — W/END EFFECTOR | ○ | ○ | ○ |
| • MAN, MANEUV UNIT/WK RESTRAINT UNIT (MMU/WRU) — W/STABILIZER | ○ | ○ | ○ |
| • MAN, MANEUV UNIT/WK RESTRAINT UNIT (MMU/WRU) — W/PAYLOAD HANDLING | | ○ | |
| • MAN, MANEUV UNIT/WK RESTRAINT UNIT (MMU/WRU) — PROXIMITY OPS MODULE | | ● | ● |
| • VERSATILE SERVICE STAGE (VSS) — W/DELIVERY, RETRIEVAL | ● | ● | ● |
| • VERSATILE SERVICE STAGE (VSS) — RENDEZ, DOCKING | | | |
| • VERSATILE SERVICE STAGE (VSS) — W/END EFFECTOR KIT | | ● | ● |
| • VERSATILE SERVICE STAGE (VSS) — W/DEBRIS CAPTURE KIT | | | ● |
| **OPTIONAL EQUIPMENT** | | | |
| • SUN SHIELD | ● | | |
| • ORBITAL STORAGE | ● | ● | |
| • ATTITUDE TRANSFER PKG | ● | ● | |
| • LIGHTING ENHANCEMENT | ● | ● | ● |
| **ADVANCED CAPABILITIES** | | | |
| • DEXTEROUS MANIPULATORS — W/RMS | ● | ● | ● |
| • DEXTEROUS MANIPULATORS — W/HPA | ● | ● | ● |
| **TOOLS** | | | |
| • HANDLING/EQUIPMENT REMOVAL | | ● | ● |

R81-0181-056(T)

Fig. 3.3-1 Service Equipment Summary

## 3.4 SERVICE EQUIPMENT REQUIREMENTS

Requirements for each item of equipment identified in Fig. 3.3-2 are contained herein. A sketch of the concept for each item is included, and tables list the requirements for the equipment and the interface requirements imposed on the spacecraft and crew.

| SERVICE EQUIPMENT | STATUS |
|---|---|
| Support Structure | |
| Retention structure | Existing (MMS FSS, trunnion fittings)/New integral, Fig. 3.4 - 1&2 |
| Special retention structure | New, Fig. 3.4 - 3&4 |
| On-Orbit Equipment | |
| Equipment stowage-on orbit support | New, Fig. 3.4 - 5&6 |
| Equipment stowage-earth return | New, Fig. 3.4 - 7&8 |
| Tilt table | Existing, (FSS, IUS, PAM-A) standard hardware Fig. 3.4 - 9&10 |
| OCP/RMS | Development hardware, Fig. 3.4 - 11&12 |
| OCP/tilt table work platform | New, Fig. 3.4 - 13&14 |
| MFR/RMS | Development hardware, Fig. 3.4- 15&16 |
| Spin table | Existing, (PAM-A, PAM-D) standard hardware Fig. 3.4 - 17&18 |
| PIDA | Development hardware, Fig. 3.4- 19&20 |
| Handling & Positioning Aid | New (concept study) Fig. 3.4 - 21&22 |
| Fluid transfer system | New, Fig. 3.4 - 23&24 |
| Non-contaminating ACS | New, Fig. 3.4 - 25&26 |
| RMS | Existing, STS standard equipment Fig. 3.4- 27&28 |
| AFD controls & displays — RMS control | Existing, STS standard hardware Fig. 3.4 - 29&30 |
| AFD controls — standard sat. checkout | New, Fig. 3.4 - 31&32 |
| AFD controls — close proximity flight control | New, Fig. 3.4 - 33&34 |
| Free Flight Systems | |
| MMU | Existing, STS standard hardware, Fig. 3.4 - 35&36 |
| MMU/WRU — end effector | New, Fig. 3.4 - 37&38 |
| — stabilizer | New, Fig. 3.4 - 39&40 |
| — payload handling | New, Fig. 3.4 - 41&42 |
| — Proximity Ops Module | New, Fig. 3.4 - 43&44 |
| Proximity Ops Module — Manned Version | New, Fig. 3.4 - 45&46 |
| MTV | Development hardware Fig. 3.4 - 47&48 |
| Proximity OPS Module — MTV Adaptation | New, Fig. 3.4 - 49&50 |
| VSS — delivery, retrieval, rendezvous & docking | New, (Concept Study) Fig. 3.4 - 51&52 |
| — end effector kit | New, Fig. 3.4 - 53&54 |
| — debris capture kit | New, Fig. 3.4 - 55&56 |
| Optional | |
| Sun shield | New, Fig. 3.4 - 57&58 |
| Orbital storage | New, Fig. 3.4 - 59&60 |
| Attitude transfer package | New, Fig. 3.4 - 61&62 |
| Lighting enhancement | New, Fig. 3.4 - 63&64 |
| Advanced Capabilities | |
| Dexterous manipulator/RMS | New, Fig. 3.4 - 65&66 |
| Dexterous manipulator/HPA | New, Fig. 3.4 - 67&68 |
| Tools | |
| MMS handling tool | New, Fig. 3.4 - 69&70 |

0181-049D
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Fig. 3.3-2 Service Equipment Status

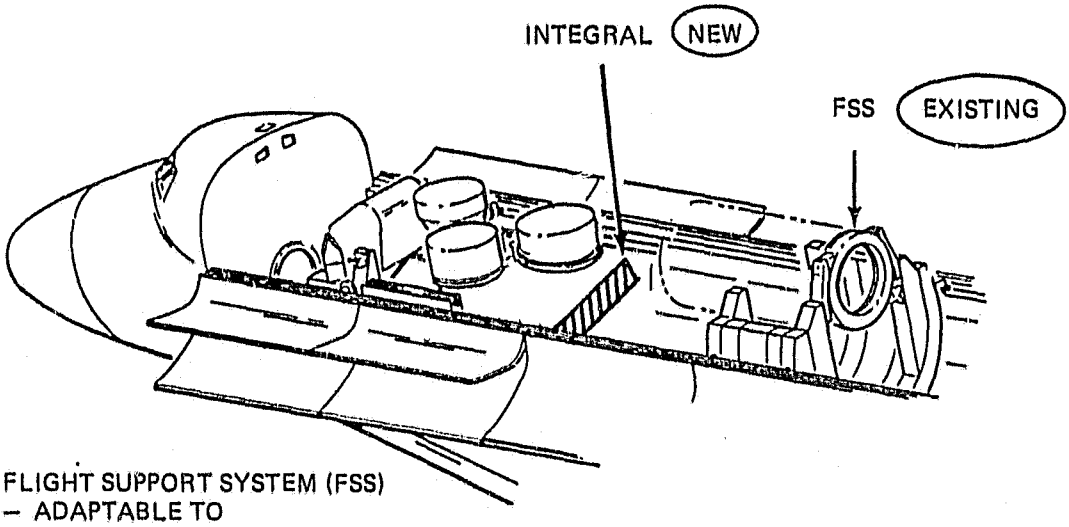
**SERVICE EQUIPMENT REQUIREMENTS: Retention Structure**

FUNCTION: Stowage of spacecraft in the Orbiter cargo bay during launch & earth return

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide structural support and mechanical attachment of the S/C to the Orbiter cargo bay | • Structural attachment fittings to S/C retention structure or trunnions for Orbiter fittings | • AFD controls & displays required for power, command signals, data and S/C release latches |
| • Provide a standardized satellite interface to enable power, command signals and data from the S/C | • Electrical power connection to S/C retention structure or Orbiter as applicable | |
| • Provide mechanism to release and latch the S/C to the S/C retention structure as applicable | • Command & data signal interface to orbiter | |
| • Provide a backup manual release and latch to the S/C retention mechanism; following release the mechanism should maintain the satellite in a "caged" condition to enable RMS attachment for deployment | | • EVA capabilities for manual release or lock of retention latches |
| • Provide AFD controls & displays for the S/C power, command signals, data and latching mechanism | | |

R81-0181-058(T)

Fig. 3.4-1 Retention Structure Requirements




- FLIGHT SUPPORT SYSTEM (FSS)
  - ADAPTABLE TO MMS-TYPE PAYLOADS
- INTEGRAL
  - BUILT INTO SATELLITE
- PALLET MOUNTED (NOT SHOWN)
  - COMPATIBLE WITH SMALL SORTIE-TYPE PAYLOADS

R81-0181-059(T)

Fig. 3.4-2 Retention Structures

**SERVICE EQUIPMENT REQUIREMENTS: Special Retention Structure**

FUNCTION: To provide cargo bay stowage for inactive satellites & space debris

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide means of grappling inactive satellites (attachment of RMS grapple fixture)<br>• Provide mounting and/or tie down support for the satellite in the Orbiter cargo bay. Mounting to match original launch vehicle interface | • None | • Control of RMS end effector<br>• Control of S/C & debris securing equipment |

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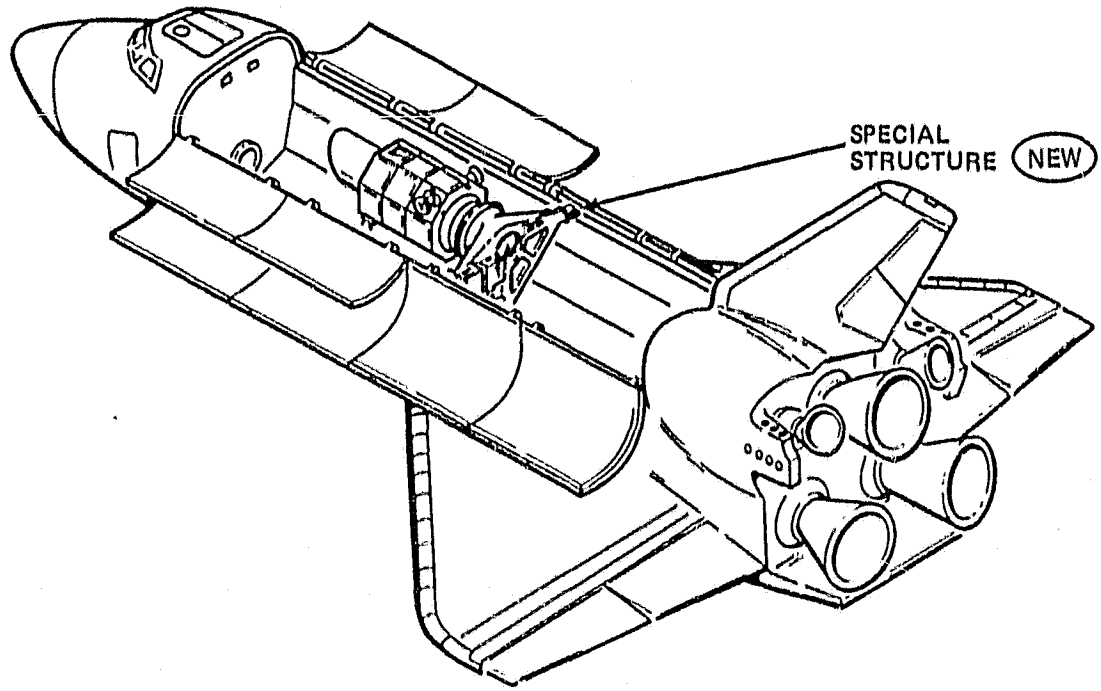
Fig. 3.4-3 Special Retention Structure Requirements

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0181-077D

Fig. 3.4-4 Concept for "Special" Retention Structure

**SERVICE EQUIPMENT REQUIREMENTS: Equipment Stowage — On Orbit Support**

FUNCTION: Orbiter cargo bay stowage of new replacement S/C equipment for servicing revisits and earth return of used S/C equipment

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide structural support and mechanical attachment of S/C equipment in the Orbiter cargo bay<br>• Provide mechanism to permit EVA release & latching of the S/C equipment | None | Crew visibility & operation of equipment release & stowage actuators via EVA |

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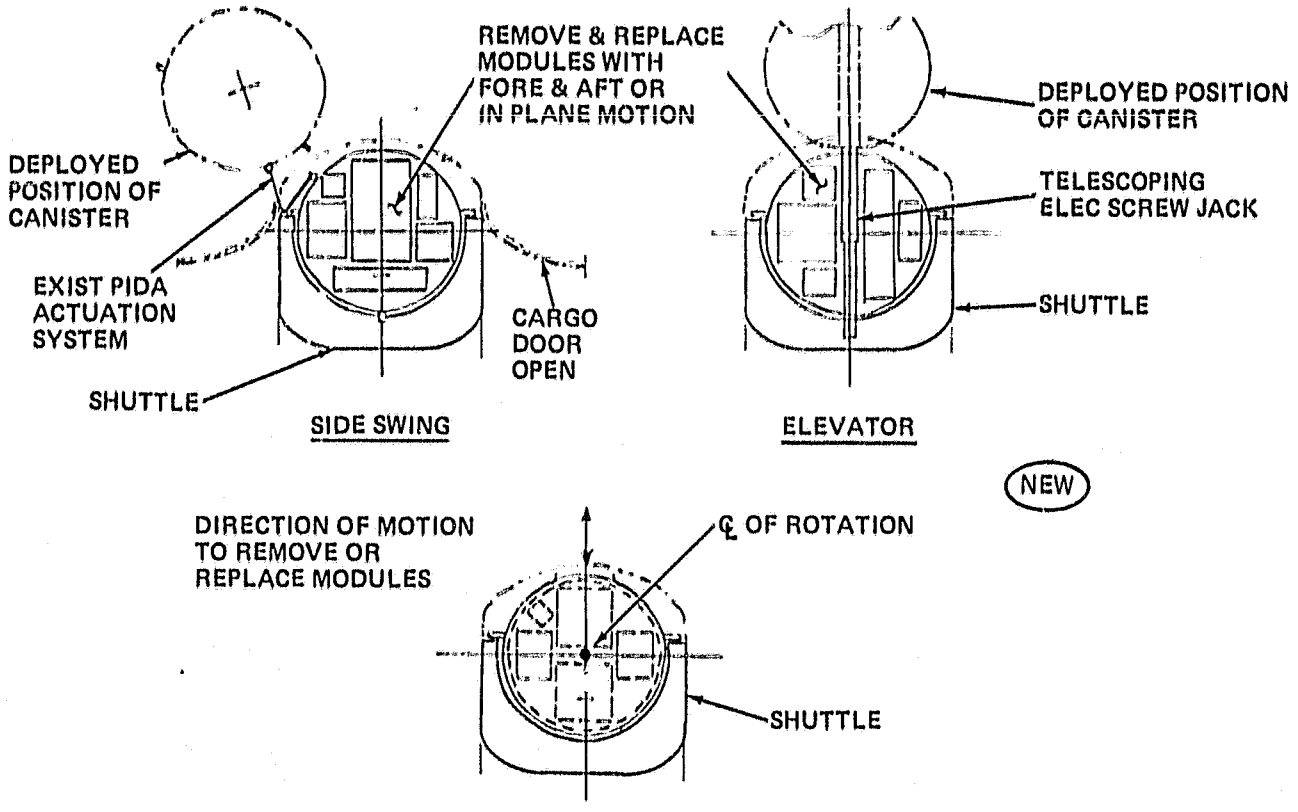
Fig. 3.4-5 Requirements for Equipment Stowage - On Orbit Support

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0181-078D

Fig. 3.4-6 Concepts for Equipment Stowage — On Orbit Support

**SERVICE EQUIPMENT REQUIREMENTS: Equipment Stowage — Earth Return**

FUNCTION: Orbiter cargo bay stowage of equipment removed from debris - spacecraft for earth return

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide structural support and mechanical attachment of S/C components to S/C flight support equipment in the cargo bay<br>• Provide mechanism to permit EVA operation of equipment retention structures | None | Crew visibility & operation of equipment stowage actuators via EVA |

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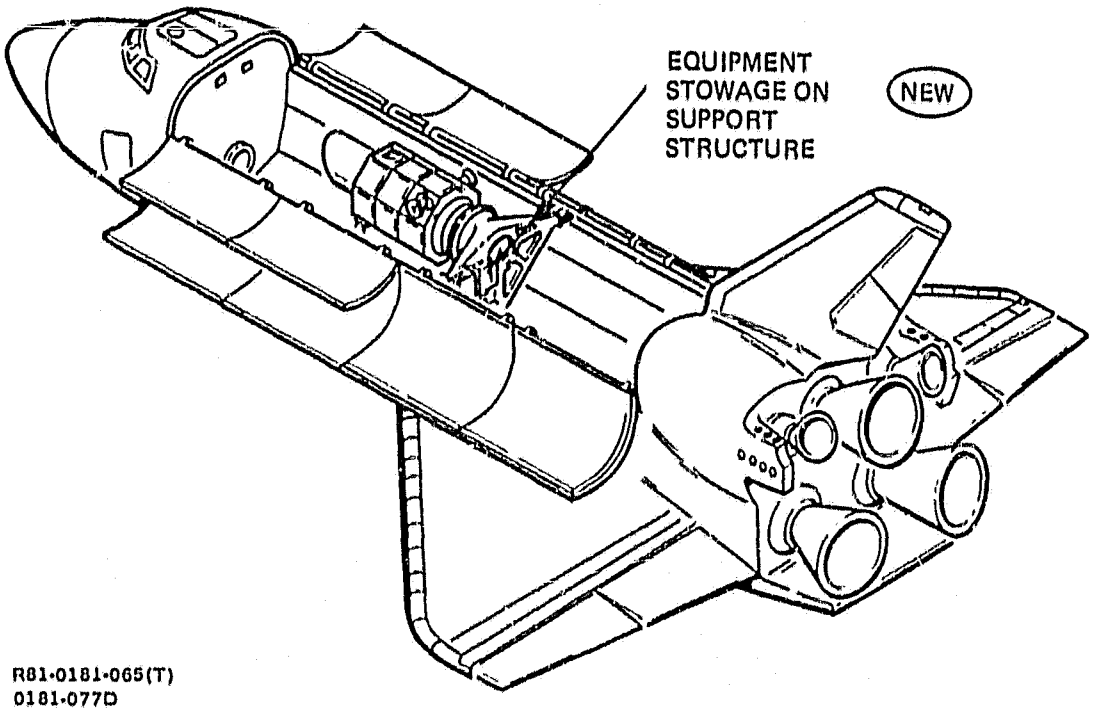
Fig. 3.4-7 Requirements for Equipment Stowage - Earth Return

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0181-077D

Fig. 3.4-8 Equipment Stowage — Earth Return Concept

**SERVICE EQUIPMENT REQUIREMENTS: Tilt Table**

FUNCTION: To rotate spacecraft out of, and into the payload bay for deployment, retrieval & positioning spacecraft for servicing

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide support for spacecraft in the Orbiter cargo bay during launch, orbital operations and landing<br>• Provide standardized latches for spacecraft release and berthing operations<br>• Provide standardized signal and power interfaces with the S/C<br>• Rotate spacecraft ≈ 90° out of the cargo bay and provide the capability of intermediate positioning<br>• Provide 360° roll capability for S/C access<br>• AFD controls & displays required for tilt table operation | • Standardized berthing interface that is compatible with the tilt table. This includes mechanical, electrical power, and signal interfaces | • AFD control of tilt table positioning |

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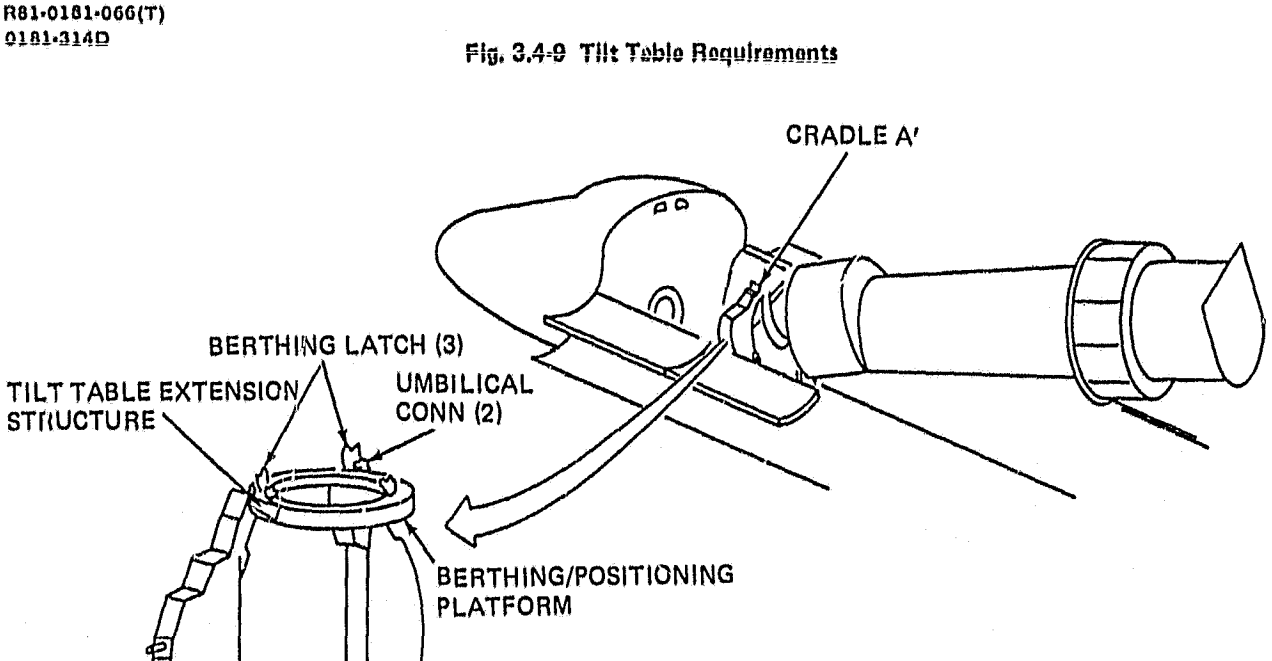
Fig. 3.4-9 Tilt Table Requirements

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0181-315D

Fig. 3.4-10 Tilt Table (MMS - FSS Adaptation)

**SERVICE EQUIPMENT REQUIREMENTS: Open Cherry Picker/RMS**

FUNCTION: To transport EVA astronaut & equipment, & provide a stable work platform for on-orbit servicing

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a platform mounted on the end of the RMS to support an EVA crewman<br>• Provide a grapple fixture on the OCP that is compatible with the RMS snare end effector<br>• Provide stowage for S/C equipment & tools<br>• Provide attachment for EMU boots on a rotating (360°) foot platform<br>• Provide a payload handling device to support S/C replaceable components and permit astronaut exhange of components<br>• An articulating stabilizer attached to the OCP base shall permit a rigid connection to be established between the OCP and work structure. The free end of the stabilizer shall have a grapple to permit attachment to S/C or Orbiter hard points.<br>• Hardline communications shall be provided between the EVA OCP operator & AFD<br>• Controls & displays shall be provided on the OCP to permit EVA astronaut control of the stabilizer & RMS for maneuvering and positioning the OCP<br>• Lights shall be provided for work site illumination<br>• Provide for OCP remote release and stowage in the Orbiter cargo bay<br>• Provide Orbiter AFD selection of control for OCP operator and control of OCP release & stowage | • Replaceable components shall be EVA compatible | • EMU support<br>• S/C equipment & tools shall be EVA compatible<br>• Controls & displays shall be EVA compatible |

R81-0181-070(T)
0181-316D

Fig. 3.4-11 Open Cherry Picker/Remote Manipulator System (OCP/RMS) Requirements

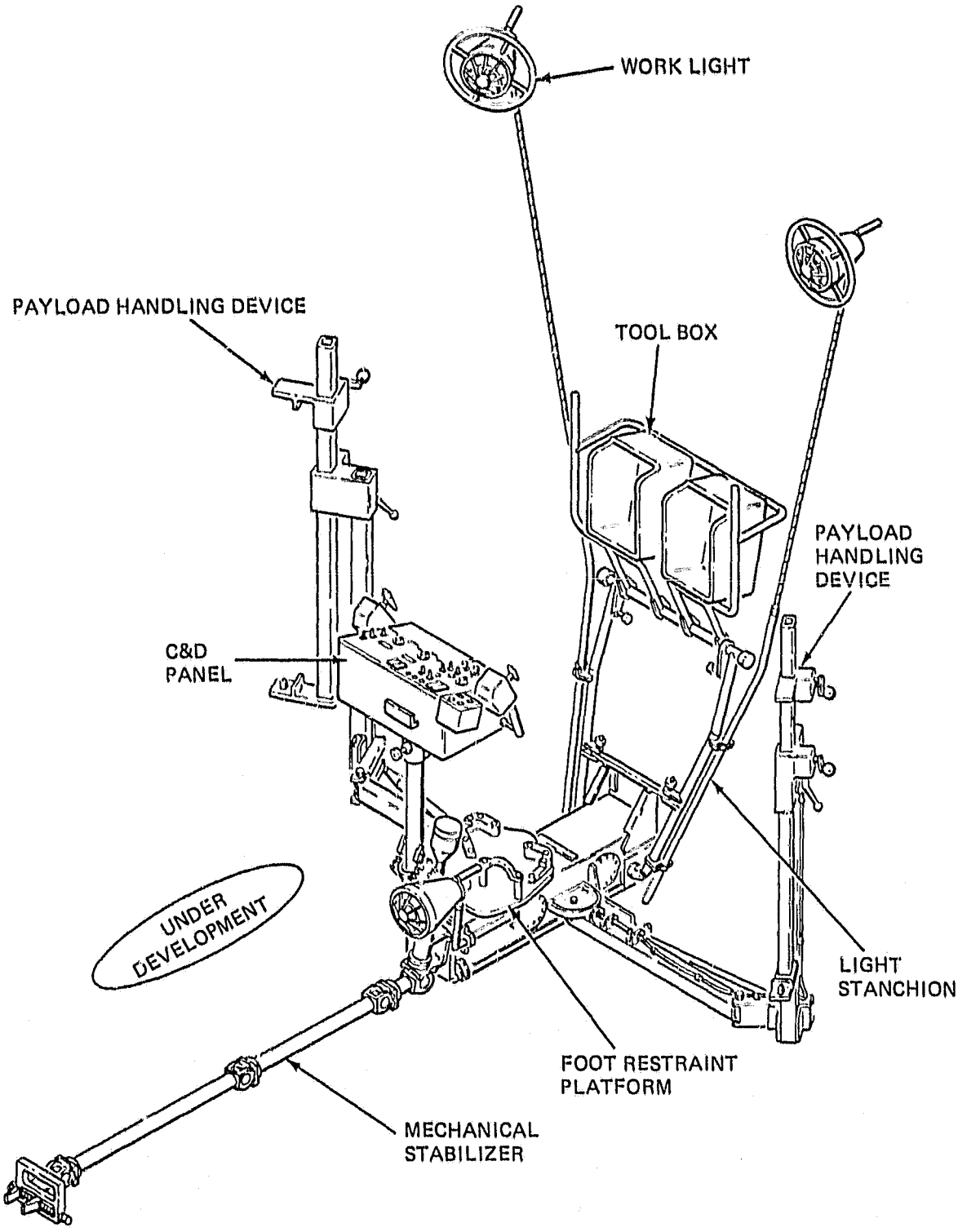


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Fig. 3.4-12 Open Cherry Picker Concept

**SERVICE EQUIPMENT REQUIREMENTS: OCP/Tilt Table Work Platform**

FUNCTION: To provide a work platform for EVA servicing of tilt table mounted spacecraft

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide OCP/EMU support restraint system; include tools & equipment stowage provisions and work lights<br>• Provide access to spacecraft by supporting the OCP with a boom that permits 1 to 3m variation in radial position from the tilt table center, and adjustable vertical position from the S/C to tilt table interface up to 10m<br>• Provide controls & displays to permit the EVA astroworker to adjust the position of the OCP to the work site. The OCP shall move with the tilt table<br>• Provide stowage for the OCP on the tilt table & mechanism for automatic deployment | None | • EMU support on work platform<br>• Controls & displays required to position OCP<br>• Tool & equipment stowage<br>• OCP deployment operations |

R81-0181-068(T)
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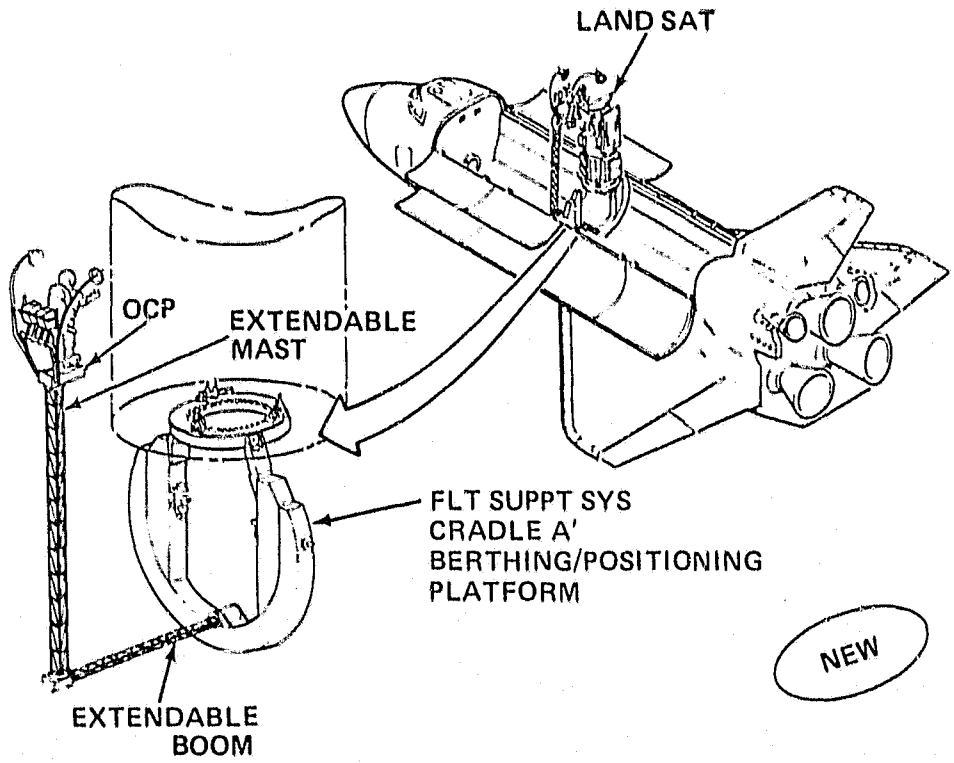
**Fig. 3.4-13 Requirements for OCP/Tilt Table Work Platform**




R81-0181-069(T)

**Fig. 3.4-14 Concept for Open Cherry Picker–Tilt Table Work Platform**

**SERVICE EQUIPMENT REQUIREMENTS: Manipulator Foot Restraint/RMS**

FUNCTION: To transport EVA astronaut & provide a stable work platform for backup situations in the payload bay

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a platform mounted on the end of the RMS to support an EVA crewman<br>• Provide a grapple fixture on the MFR that is compatible with the RMS snare end effector<br>• Provide stowage for tools<br>• Provide attachment for EMU boots on a rotating (360°) foot platform<br>• Provide for MFR remote release & stowage in the Orbiter cargo bay<br>• Provide Orbiter AFD control of MFR release & stowage | • Replaceable equipment shall be EVA compatible | • EMU support<br>• S/C equipment & tools shall be EVA compatible |

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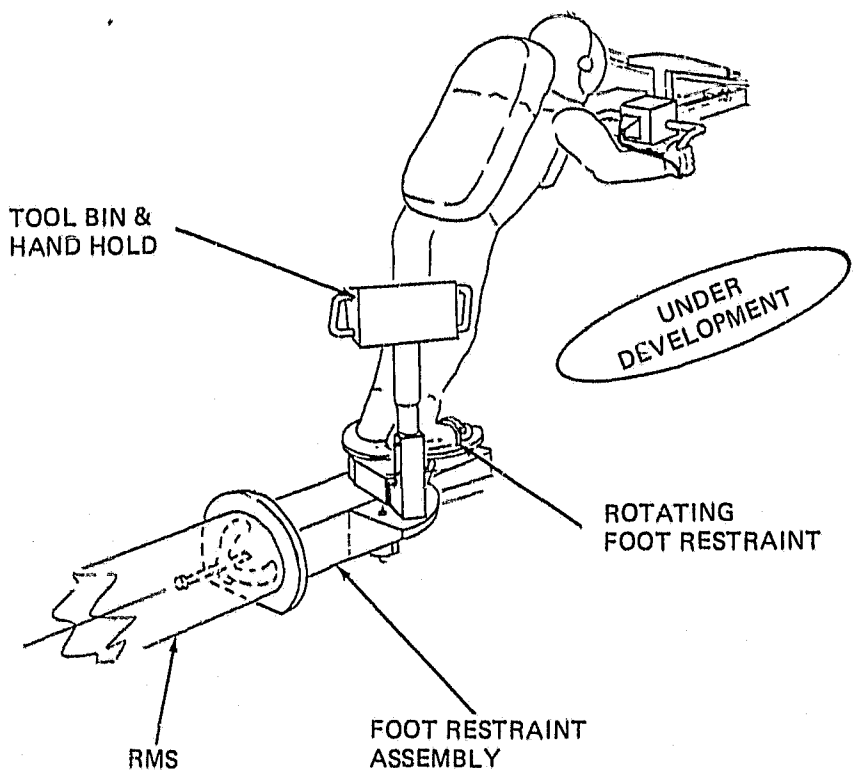
**Fig. 3.4-15 Manipulator Foot Restraint/Remote Manipulator System (MFR/RMS) Requirements**




R81-0181-073(T)

**Fig. 3.4-16 Manipulator Foot Restraint Concept**

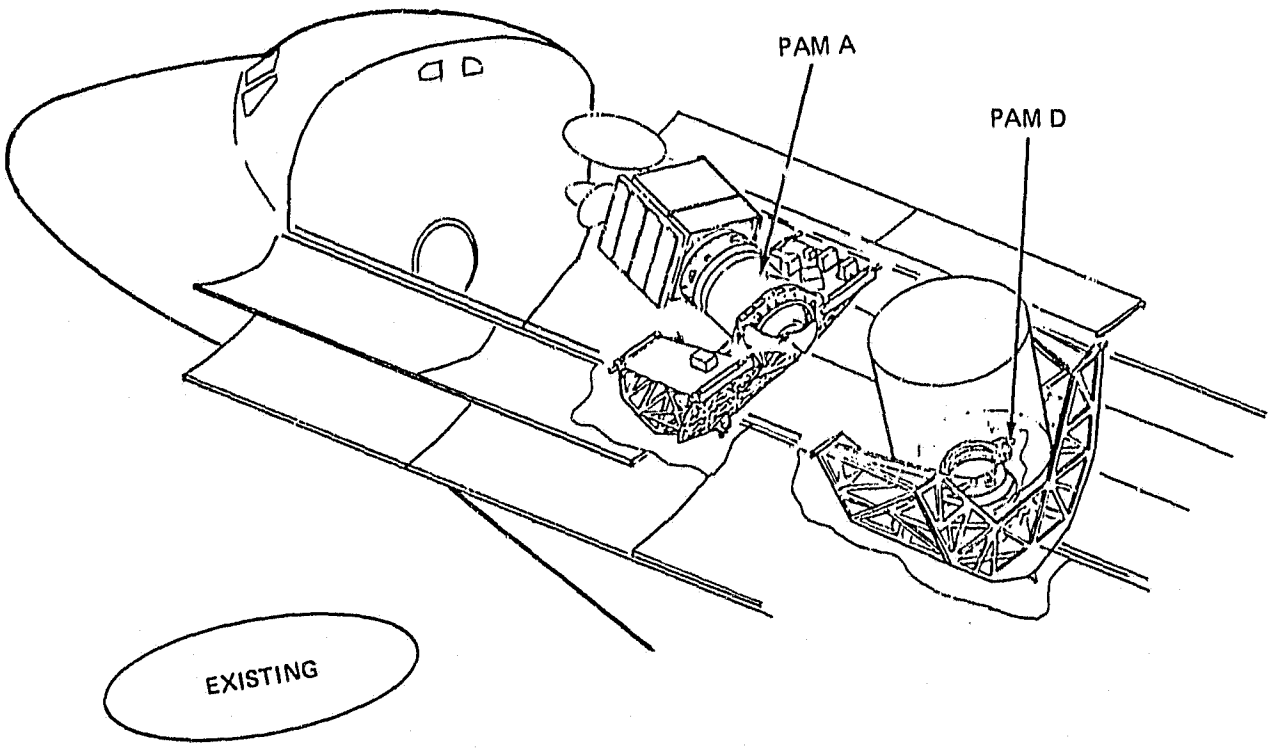
**SERVICE EQUIPMENT REQUIREMENTS: Spin Table**

FUNCTION: To spin-up spacecraft and impart separation ΔV

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide support for spacecraft in the Orbiter cargo bay during launch and orbital operations<br>• Provide retention/release mechanism for SRM/payload separation from the Orbiter.<br>• Provide signal and power interfaces to the SRM/payload<br>• Rotate spacecraft 90° out of the cargo bay if required (ref PAM A)<br>• Provide separation ΔV of up to 6 ft/sec<br>• AFD controls & displays required for spin table operation/payload release | None | • AFD control of spin table operations |

R81-0181-074(T)
0181-320D

Fig. 3.4-17 Spin Table Requirements




R81-0181-075(T)

Fig. 3.4-18 Spin Table – PAM A, PAM D Solid Rocket Stage Adaptations

**SERVICE EQUIPMENT REQUIREMENTS: Payload Installation and Deployment Aid**

FUNCTION: To move large, heavy payloads out of and into the Orbiter cargo bay

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Accommodate deployment & stowage of payloads up to 4.6 m dia x 18.3 m long & 289 kN<br>• Move payloads without exceeding cargo bay 76 mm (3.0 inch) clearance envelope<br>• Design to stow under closed doors with large payload in cargo bay<br>• Provide means of positioning PIDA to deploy and receive payload<br>• Provide line of sight release & docking mechanism outside of cargo bay<br>• Provide energy absorption at docking interface<br>• AFD displays and controls required for payload release and capture | • Passive docking interfaces to mate with PIDA | • Operate PIDA controls in AFD |

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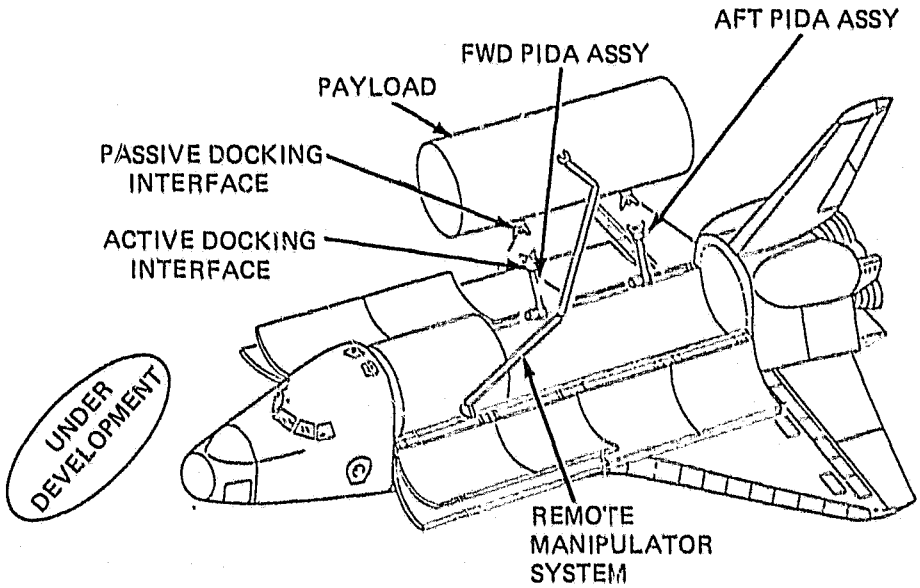
0181-322D

Fig. 3.4-19 Requirements for Payload Installation and Deployment Aid (PIDA)




R81-0181-077(T)
0181-323D

Fig. 3.4-20 Concept for Payload Installation and Deployment Aid (PIDA)

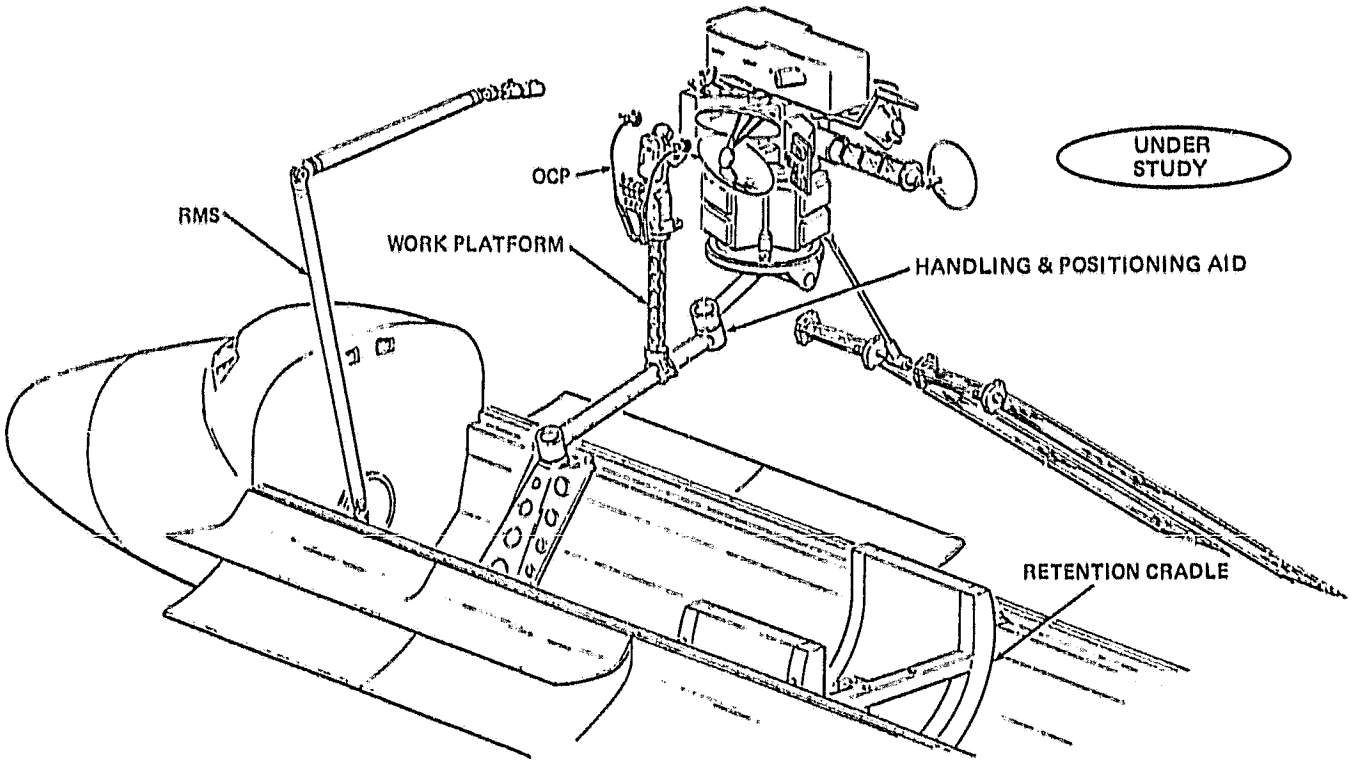
## SERVICE EQUIPMENT REQUIREMENTS: Handling & Positioning Aid

FUNCTION: To provide a standard fixture to support S/C during on-orbit servicing

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a standard structural attachment (HPA) of S/C during orbital servicing that is completely clear of the cargo bay<br>• Provide a standard location in the Orbiter cargo bay for the HPA<br>• Provide means of rotating and tilting the S/C to facilitate access and deployment of S/C appendages<br>• Provide a standard umbilical for power, command signals to, and data from the S/C<br>• Provide a standard fluid connector interface to enable S/C refueling<br>• Provide the active half of a S/C berthing mechanism<br>• Provide a mechanism to impart separation velocity of at least 1 ft/sec to spacecraft<br>• Provide an extendable boom mounted on the HPA with an OCP and work platform for EVA crew servicing operations<br>• Provide for transfer of attitude & state vector information to S/C prior to deployment<br>• Provide a spin table capable of launching satellites<br>• Provide AFD controls & displays required for maneuvering the HPA and positioning the work platform | • Standardized berthing interface compatible with the HPA. This includes mechanical, electrical power, signal and fluid interfaces | • AFD controls & displays required for maneuvering the HPA & positioning work platform<br>• EMU support on work platform: |

R81-0181-080(T)

Fig. 3.4-21 Handling & Positioning Aid (HPA) Requirements




R81-0181-081(T)

Fig. 3.4-22 Handling & Positioning Aid Concept

## SERVICE EQUIPMENT REQUIREMENTS: Fluid Transfer System

FUNCTION: To provide for the replenishment of S/C propulsion propellants and satellite fluid expendables

| SUPPORT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide equipment to remotely replenish S/C propulsion and fluid subsystems<br>• Provide a standard fluid connector to interface with the HPA to enable fluid transfer to the HPA -- spacecraft interface.<br>• Provide fluid storage tank(s) in the Orbiter cargo bay, a means of mating fluid connections to the HPA & a pressure source to effect fluid transfer<br>• All connections to the HPA, to effect fluid transfer, shall be made/checked-out on the ground prior to launch<br>• Design fluid transfer system to accommodate:<br>-- Hypergolic propellants<br>-- Fluids: xenon, propane, carbon dioxide, argon<br>-- Solid cryogenic: methane ammonia, neon, nitrogen, helium, carbon dioxide | • Provide mating connections for fluid replenishment compatible with HPA<br>• Provide redundant shut off valves to isolate fluid connections | • Control of propellant transfer operation |

R81-0181-082(T)

Fig. 3.4-23 Fluid Transfer System Requirements

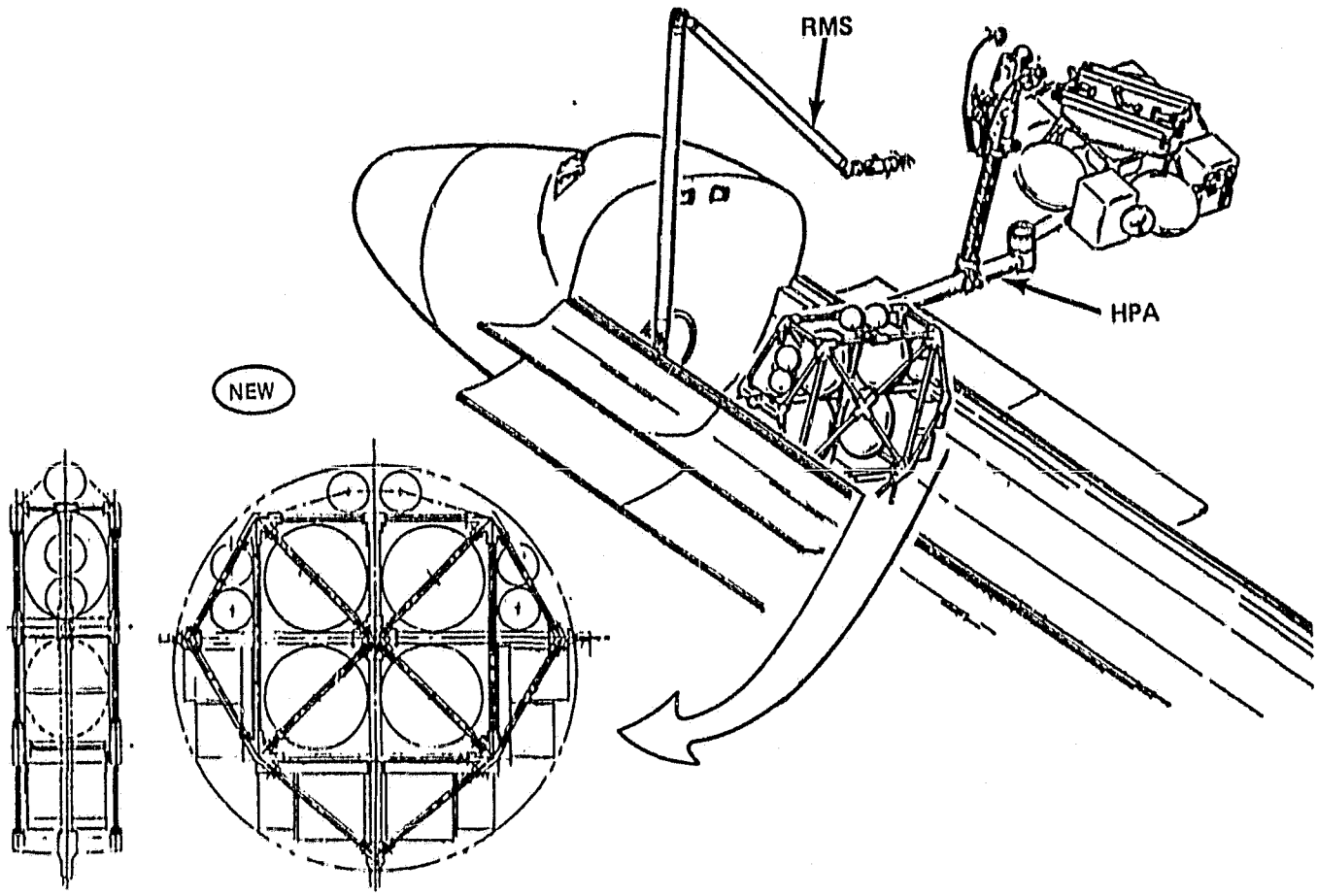



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Fig. 3.4-24 Fluid Transfer Concept

**SERVICE EQUIPMENT REQUIREMENTS: Non-contaminating ACS**

FUNCTION: To provide Orbiter attitude control when RCS operation would be detrimental to contamination-sensitive S/C

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide cargo bay mounted attitude control system that utilizes minimum cargo bay length<br>• Design approach shall not contaminate S/C during servicing or retrieval operations<br>• Dead band design point ±0,01°/axis & a stability rate of ± 0,01°/sec/axis<br>• The control system shall stabilize the Orbiter for 5 hr/mission<br>• Provide controls to deploy and activate ACS as applicable | None | • Activate non-contamination ACS |

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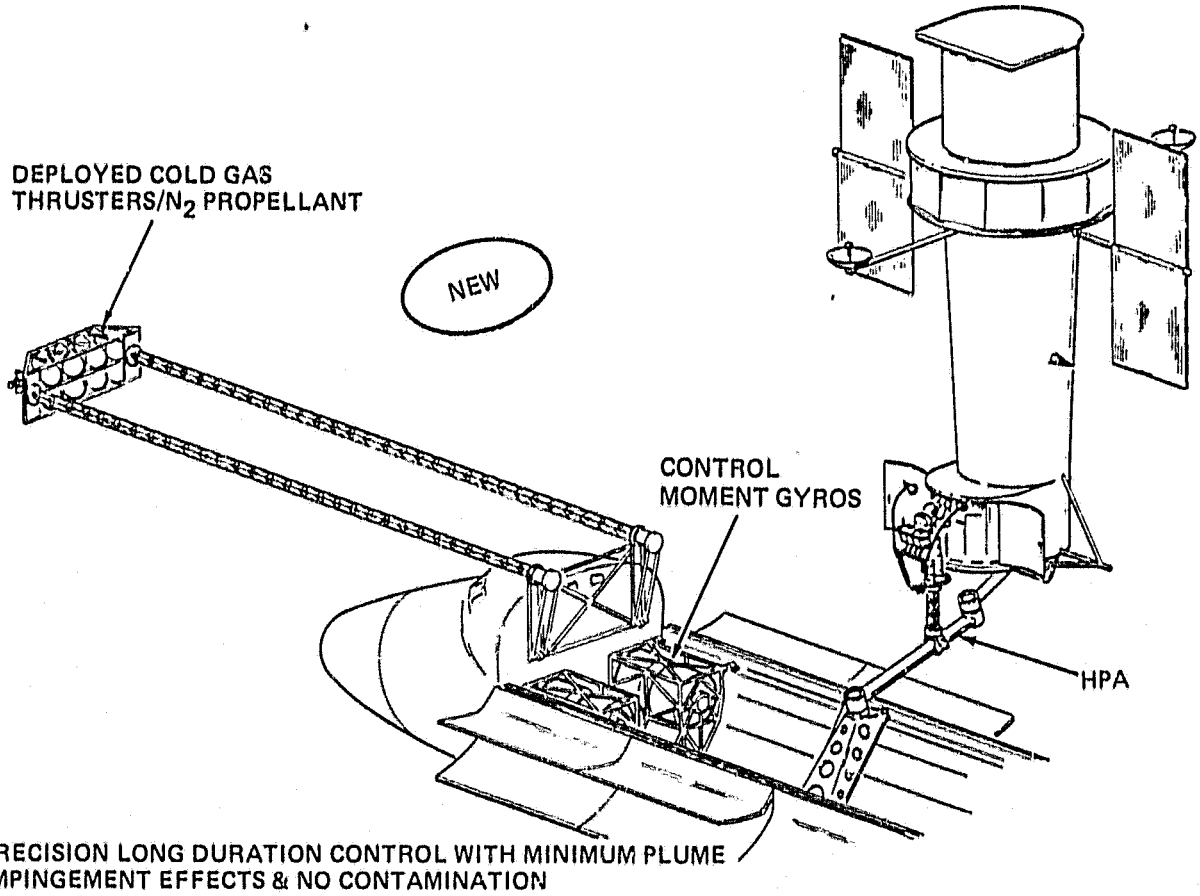
R81-0181-084(T)

Fig. 3.4-25 Requirements for Non-Contaminating ACS




- PRECISION LONG DURATION CONTROL WITH MINIMUM PLUME IMPINGEMENT EFFECTS & NO CONTAMINATION

0181-082D
R81-0181-085(T)

Fig. 3.4-26 Concept for Non-Contaminating Attitude Control System

**SERVICE EQUIPMENT REQUIREMENTS: Remote Manipulator System**

FUNCTION: To deploy spacecraft from the cargo bay, retrieve free flying spacecraft, then berth them on support structure

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide means of grasping S/C located anywhere in the Orbiter cargo bay<br>• Remove S/C up to 65,000 lb from the cargo bay and orient them for release<br>• Provide means of imparting a separation velocity to S/C and releasing them on command<br>• Grapple free flying S/C up to 32,000 lb and manuever them to a berthing fixture in the cargo bay<br>• Provide a standardized snare end effector for grappling operations<br>• Provide controls & displays; cargo bay visibility to permit AFD crew operation of the RMS<br>• Provide structural support for the RMS during Orbiter launch and landing and when not in use during orbital operations | • Provide mounting for a grapple fixture located close to the S/C center of gravity | • Operation of the RMS controls in the AFD |

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Fig. 3.4-27 Remote Manipulator System Requirements

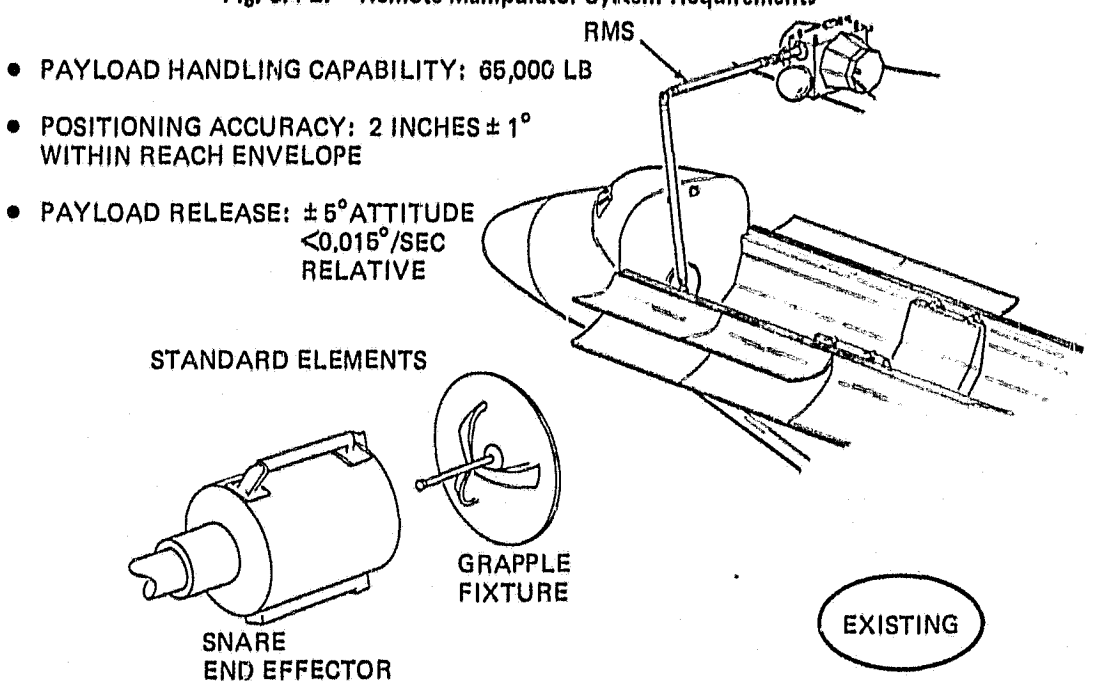


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Fig. 3.4-28 Remote Manipulator System (RMS)

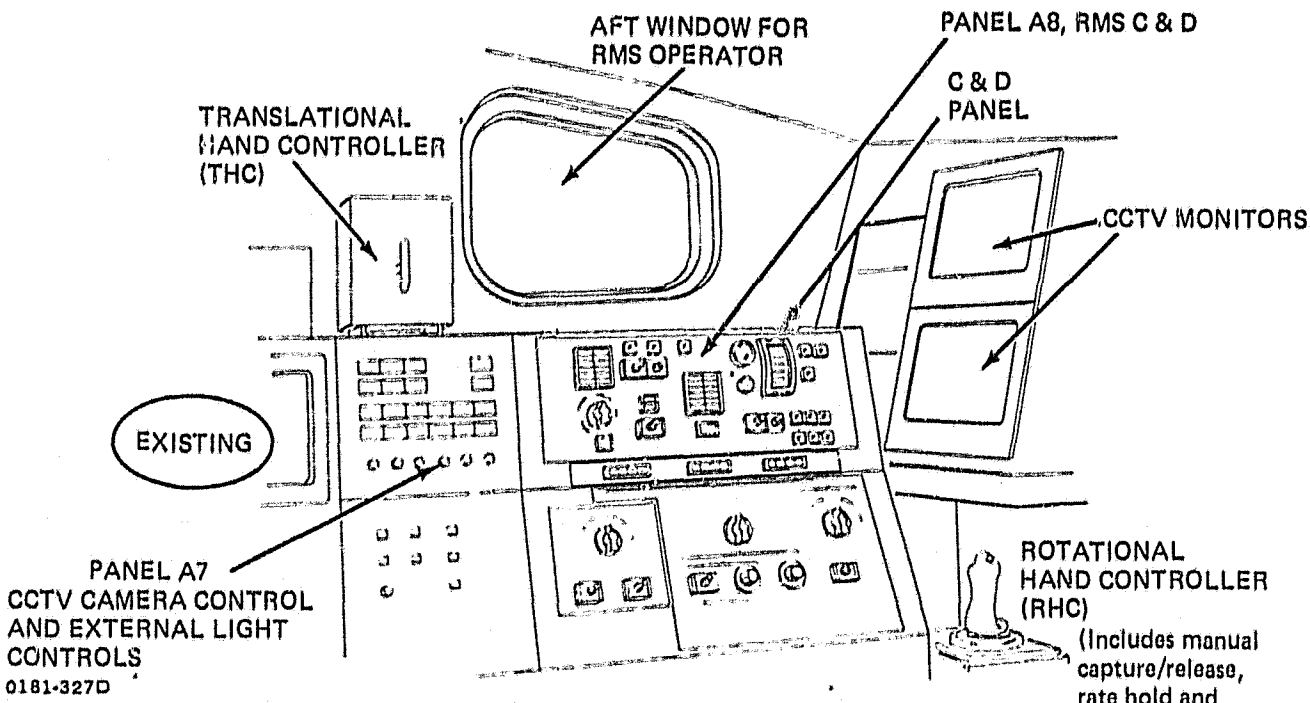
**SERVICE EQUIPMENT REQUIREMENTS: AFD Controls/Displays — RMS Control**

FUNCTION: To provide controls and displays required for RMS operation

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide switches to activate RMS<br>• Provide hand controllers for RMS translation and attitude excursions<br>• Provide direct, "out the window" view of the cargo bay area for the RMS operators<br>• Provide CCTV for RMS operation when direct view obscured<br>• Provide RMS tip positional information<br>• Provide C & W to alert the operator to conditions that could damage the RMS<br>• Provide different control mode references (eg, cargo bay, end effector) to assist operator in maneuvering RMS<br>• Provide controls to operate camera, lights, and snare end effector | None | • Operation of the RMS from the Orbiter AFD |

0181-326D
R81-0181-086(T)

Fig. 3.4-29 Requirements for AFD Controls/Displays — RMS Control




0181-327D
R81-0181-087(T)

Fig. 3.4-30 RMS Operator Station

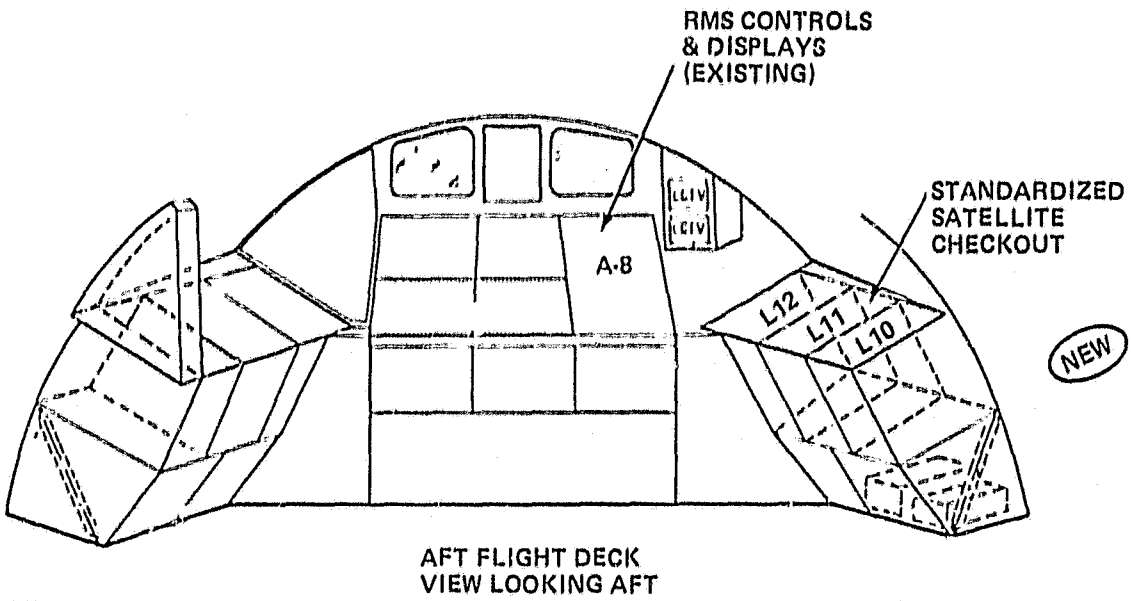
**SERVICE EQUIPMENT REQUIREMENTS: AFD Controls/Displays — Standardized Satellite Checkout**

**FUNCTION: To provide standardized checkout of spacecraft prior to deployment**

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a standardized AFD control console to checkout spacecraft prior to deployment<br>• Provide appropriate displays to verify spacecraft status<br>• Provide controls/displays to deploy spacecraft from the HPA | • Accept interrogation signals & provide response | • Operation of controls & interpretation of data |

R81-0181-088(T)

**Fig. 3.4-31 Requirements for AFD Controls/Displays — Standardized Satellite Checkout**




R81-0181-089(T)

**Fig. 3.4-32 Potential Locations of Aft Flight Deck (AFD) Standardized Satellite Checkout Control Panel**

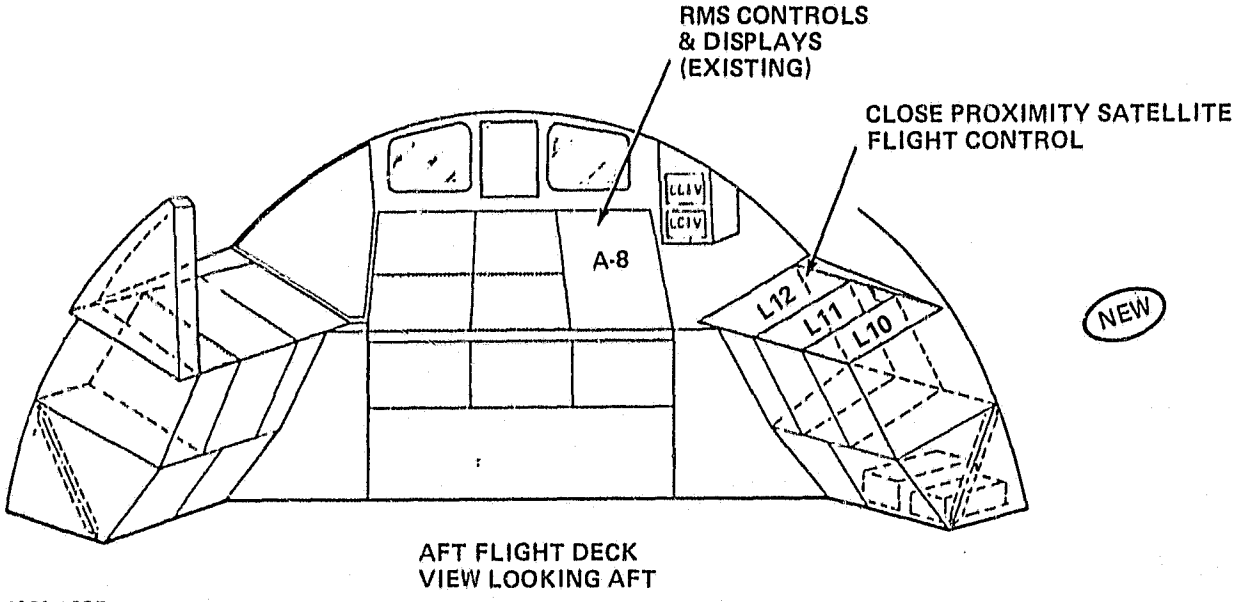
**SERVICE EQUIPMENT REQUIREMENTS: AFD Controls/Displays — Close Proximity Flight Control**

FUNCTION: To provide AFD controls & displays for flight control of spacecraft in close proximity to the Orbiter

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a control panel to be used for close proximity flight control of free flying spacecraft to bring them within the RMS reach distance for capture<br>• Provide spacecraft position, range & range rate displays<br>• Provide controllers for rotation & translation control of the spacecraft | • Accept control signals & provide S/C positional data | Operation of controls & interpretation of displayed data |

0181-059D
R81-0181-090(T)

**Fig. 3.4-33 Requirements for AFD Controls/Displays — Close Proximity Flight Control**




0181-083D
R81-0181-091(T)

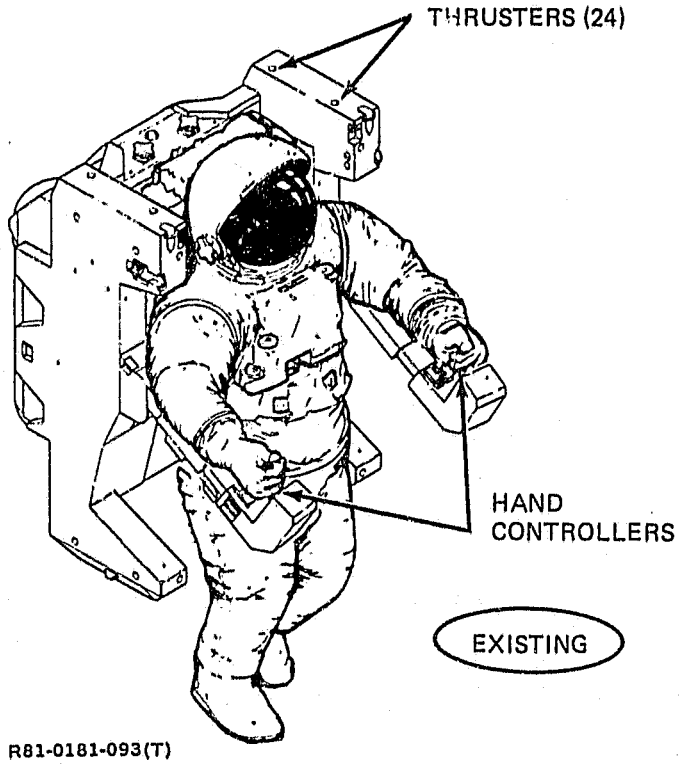
**Fig. 3.4-34 Potential Locations of Aft Flight Deck (AFD) Close Proximity Flight Control Panel**

**SERVICE EQUIPMENT REQUIREMENTS: Manned Maneuvering Unit (MMU)**
FUNCTION: Free flyer to transport one EVA crew & equipment to worksite

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a self contained propulsion unit that attaches to an astronaut<br>• Provide cold gas propulsion to permit rotation & translation in any direction<br>• MMU hover capability shall be provided<br>• Provide hand controllers, one for rotation the other for translation, convenient for use during EVA<br>• A clear work zone must be provided in front of the astronaut<br>• Provide attachment interface for a Work Restraint Unit (WRU)<br>• Support structure & associated release mechanism shall be provided for the MMU in the Orbiter cargo bay<br>• An MMU recharge/replenishment station is required in the cargo bay | • Replaceable components shall be compatible with EMU/EVA operations | • Operation of MMU controls during maneuvers |

R81-0181-092(T)
0181-328D

**Fig. 3.4-35 Manned Maneuvering Unit (MMU) Requirements**




R81-0181-093(T)

**Fig. 3.4-36 Manned Maneuvering Unit (MMU)**

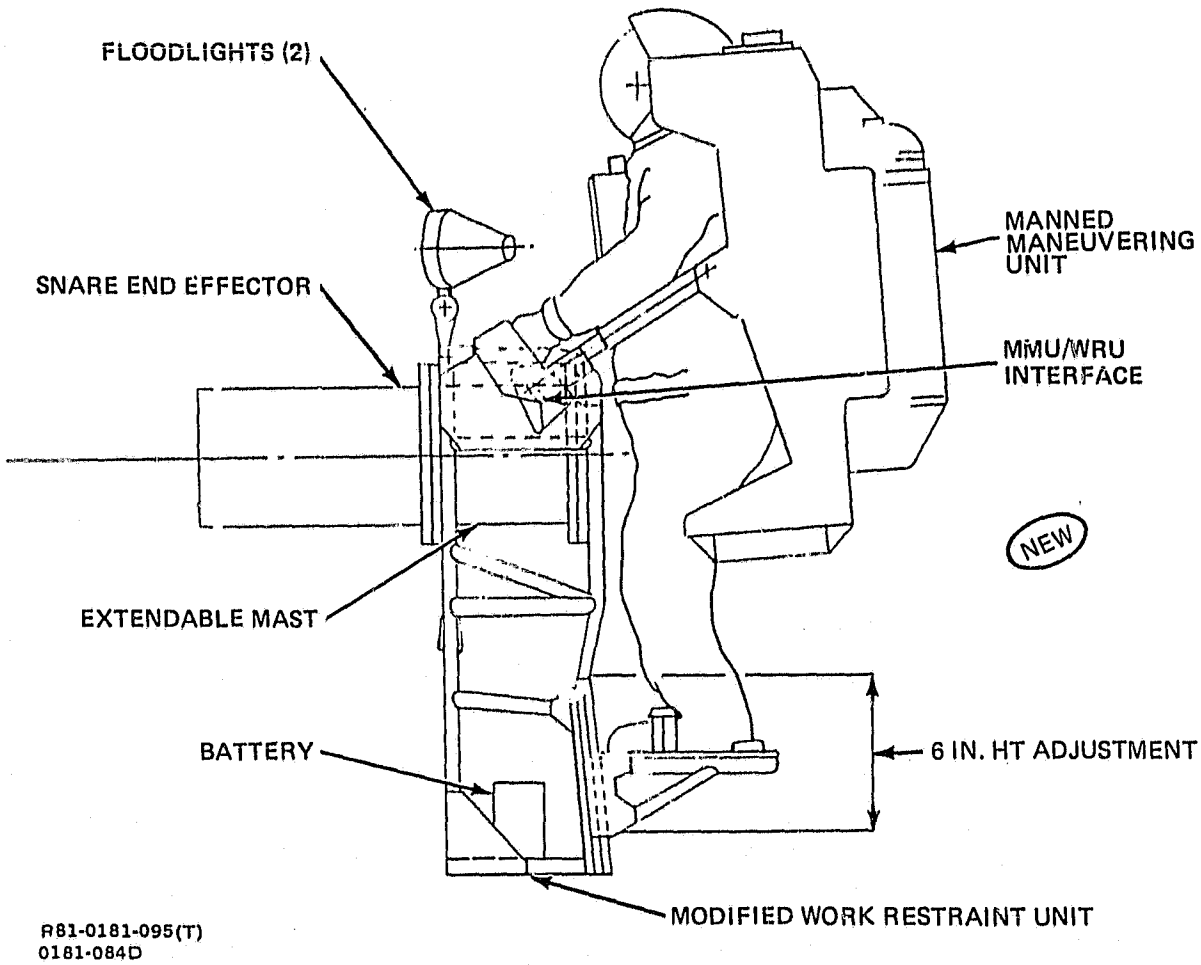
**SERVICE EQUIPMENT REQUIREMENTS: MMU/WRU – End Effector Adaptation**

FUNCTION: To grapple and deploy spacecraft with the MMU/WRU during RMS – inoperative situations

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a snare end effector mounted on an extendable boom<br>• Attach the end-effector assembly to the WRU in front of the crewman, convenient to line-of-sight<br>• Provide lighting, alignment & distance cues for the operator<br>• Provide EVA compatible Controls & Displays for operation of the snare end effector/boom<br>• Make provisions for MMU/WRU stowage in the payload bay | • Install an RMS compatible grapple fixture, at the S/C cg, accessible to an end effector | • Operation of MMU flight controls<br>• Operation of snare end effector/boom |

R81-0181-094(T)
0181-060D

**Fig. 3.4-37 Requirements for MMU/WRU – End Effector Adaptation**




R81-0181-095(T)
0181-084D

**Fig. 3.4-38 Concept for MMU/WRU – End Effector Adaptation**

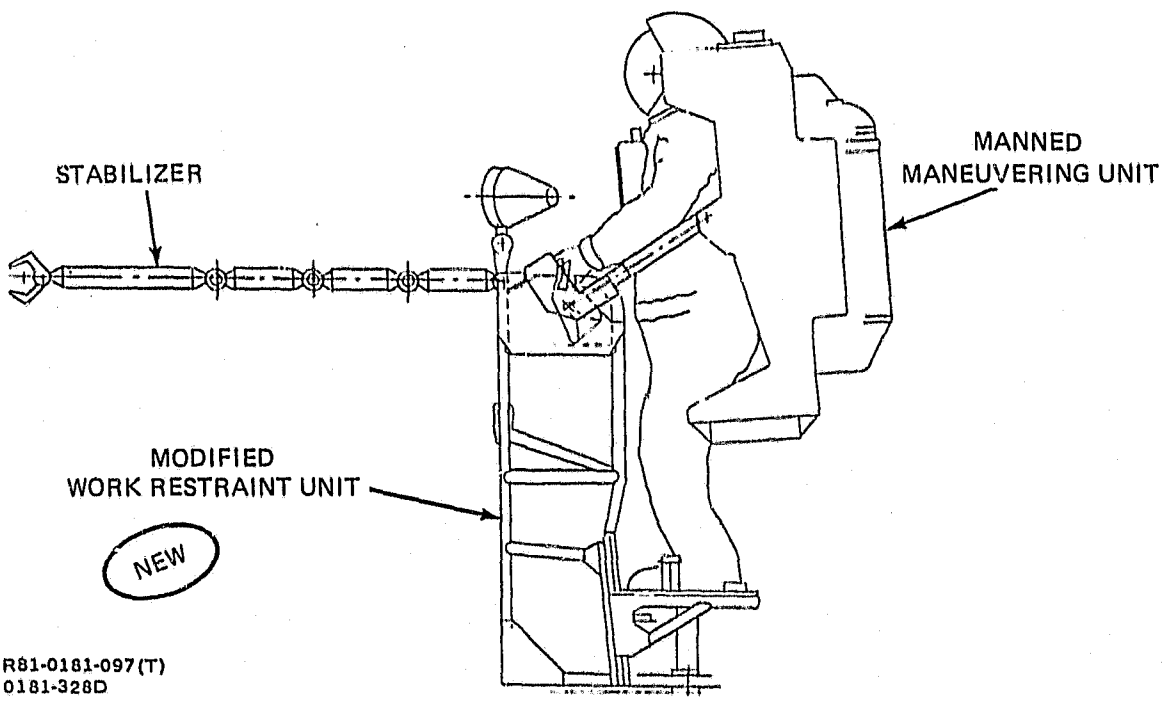
**SERVICE EQUIPMENT REQUIREMENTS: MMU/WRU – Stabilizer Adaptation**

FUNCTION: To stabilize the MMU/WRU at a worksite to backup mechanical hangup situations with the RMS inoperative, and to support manual release of satellite appendages

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a stabilizer on the WRU to attach to the worksite<br>• Provide clamping jaws on the end of the stabilizer for worksite attachment<br>• Provide a means of rigidizing and derigidizing the stabilizer<br>• Locate the stabilizer within WRU operator reach for attachment to the worksite<br>• The stabilizer should be approximately 5 ft long and permit MMU/WRU relocation within a semisphere described about the stabilizer attachment point<br>• EVA compatible controls to operate stabilizer jaws and rigidize/derigidize<br>• Make provisions for MMU/WRU stowage in the payload bay | • Stabilizer attachment point | • Operation of MMU flight controls<br>• Operation of stabilizer |

R81-0181-096(T)

**Fig. 3.4-39 Requirements for MMU/WRU-Stabilizer Adaptation**




R81-0181-097(T)
0181-328D

**Fig. 3.4-40 Concept for MMU/WRU Stabilizer Adaptation**

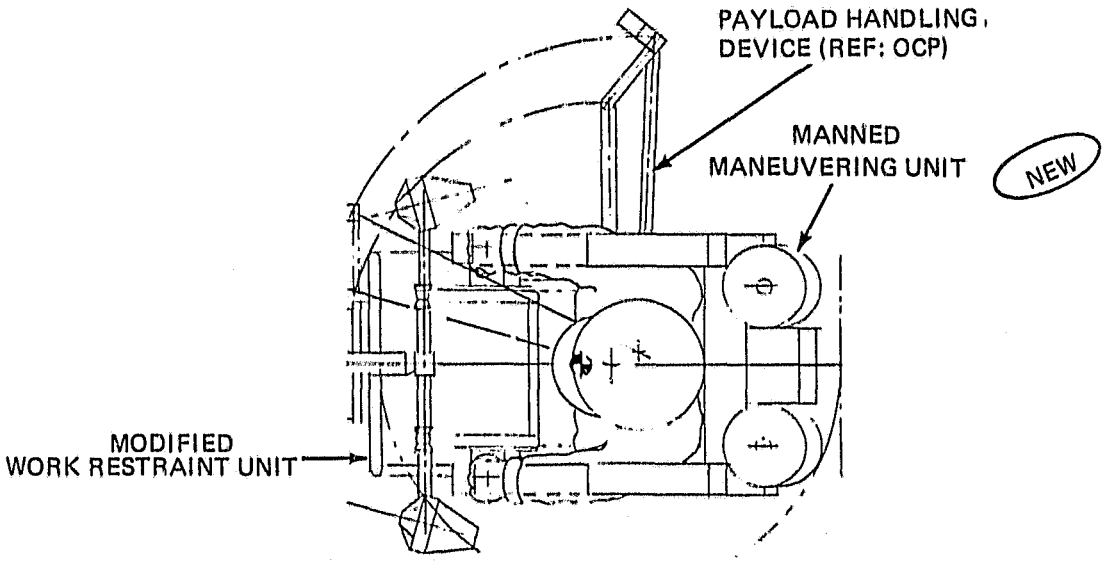
**SERVICE EQUIPMENT REQUIREMENTS: MMU/WRU – Payload Handling Adaptation**

FUNCTION: To enable the MMU/WRU to transport S/C equipment for servicing during RMS inoperative situations.

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a payload handling device on the MMU/WRU<br>• The payload handling device shall be capable of transporting S/C replaceable equipment such as MMS modules<br>• Controls for operating the payload handling device shall be EVA compatible<br>• Make provisions for MMU/WRU stowage in the payload bay | None | • Operation of MMU flight controls<br>• Operation of the payload handling device |

0181-062D
R81-0181-098(T)

**Fig. 3.4-41 Requirements for MMU/WRU – Payload Handling Adaptation**




R81-0181-099(T)
0181-329D

**Fig. 3.4-42 Concept for MMU/WRU – Payload Handling Adaptation**

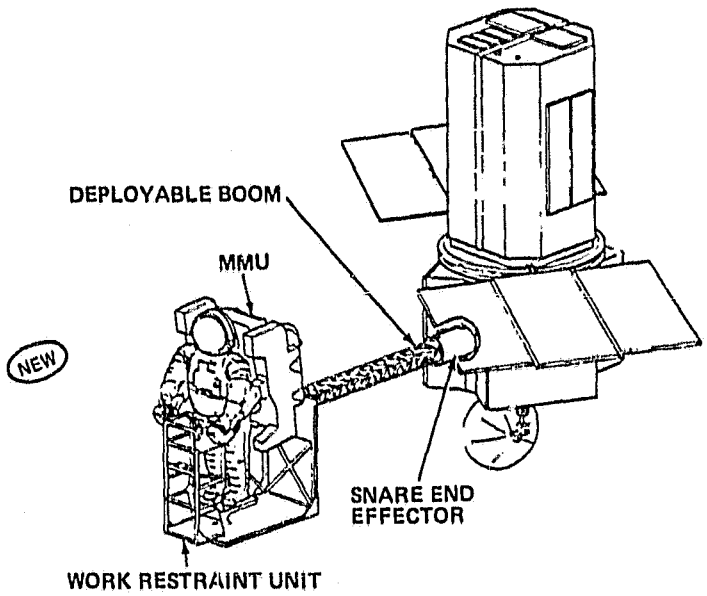
**SERVICE EQUIPMENT REQUIREMENTS: Proximity Operations Module (POM) - MMU/WRU Adaptation**

FUNCTION: Manned retrieval of MMS-type satellites at 1000 ft separation from Orbiter

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a Work Restraint Unit (WRU) compatible with the MMU that will enable retrieval of satellites weighing about 5000 lb<br>• Provide an MMU mechanical attachment to the WRU<br>• Mount to the WRU an RMS snare end-effector/extendable boom that extends an adequate distance to permit grappling and towing of a S/C<br>• Provide a rotating pivot at the snare end-effector/extendable boom interface to enable the S/C cg to align itself with the POM's thruster axis/tow force vector<br>• Provide a hover/fly-around capability to enable inspection of the satellite prior to capture<br>• Provide crew visibility to maneuver and attach the snare end-effector to the S/C's grapple fixture<br>• Provide lighting and snare alignment cues for the operator<br>• Provide a rotating foot restraint platform on the WRU with two locking positions: one aligned with the snare end-effector/boom and the other at 180° to enable towing of a S/C<br>• Provide EVA-compatible controls on the WRU for operation of the snare end-effector/boom and rotating foot restraint platform<br>• Make provisions for POM storage in the payload bay | • Provide an RMS - compatible grapple fixture mounted as close as practical to the S/C cg | • Operation of MMU flight controls<br>• Controls and displays for snare/boom operation |

R81-0181-100(T)

Fig. 3.4-43 Requirements for Proximity Operations Module — MMU/WRU Adaptation




R81-0181-101(T)

Fig. 3.4-44 Concept for Proximity Operations Module — MMU/WRU Adaptation

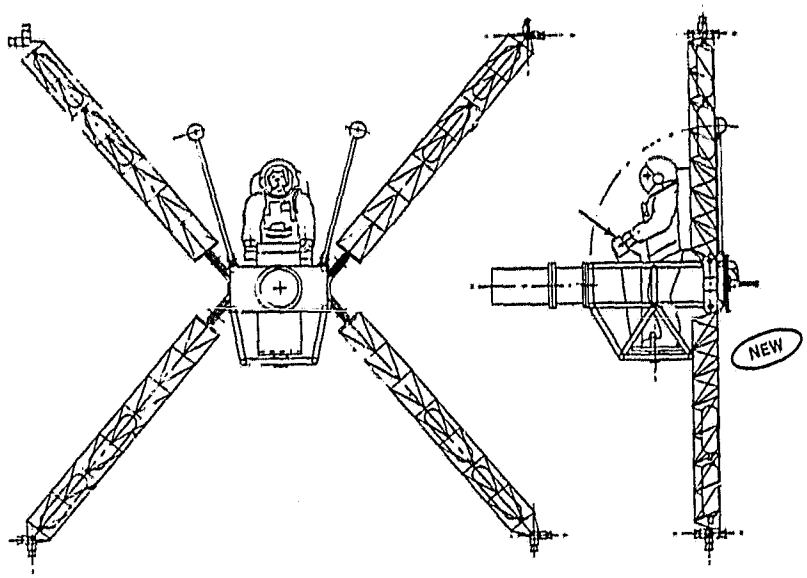
**SERVICE EQUIPMENT REQUIREMENTS: Proximity Operations Module (POM) - Manned Version**

FUNCTION: Manned retrieval of large, heavy satellites at 1000 ft separation from Orbiter

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a manned vehicle that will retrieve satellites weighing up to 32,000 lb<br>• Provide a cold gas propulsion system to permit rotational/ translational maneuvers in any direction<br>• Locate thrusters to minimize plume impingement on the satellite<br>• Provide an RMS snare end-effector/extendable boom that extends an adequate distance to permit grappling and towing of a S/C<br>• Provide a hover/fly-around capability to enable inspection of the satellite prior to capture<br>• Provide crew visibility to maneuver and attach the snare end-effector to the S/C's grapple fixture<br>• Provide lighting and alignment cues for the operator<br>• Provide a rotating foot restraint platform on the vehicle with two locking positions: one aligned with the snare end-effector/boom and the other at 180° to enable towing of a S/C<br>• Provide EVA-compatible controls for flying the vehicle, operating the snare end-effector/ boom, and rotating foot restraint platform<br>• Mount a grapple fixture on the vehicle to enable deployment and retrieval by the RMS<br>• Make provisions for storing the vehicle in the payload bay | • Provide an RMS-compatible grapple fixture mounted as close as practical to the S/C cg | • Controls & displays associated with POM boom & snare operation |

R81-0181-102(T)

**Fig. 3.4-45 Requirements for Proximity Operations Module — Manned Version**




R81-0181-103(T)

**Fig. 3.4-46 Concept for Proximity Operations Module — Manned Version**

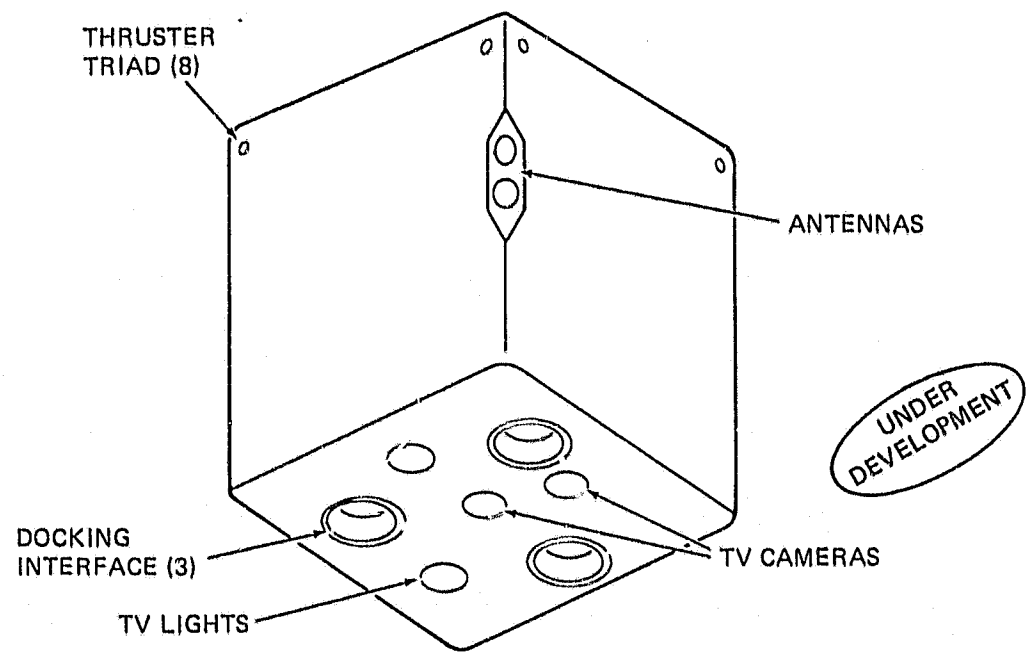
**SERVICE EQUIPMENT REQUIREMENTS: Maneuverable Television (MTV)**

FUNCTION: Visual remote examination of satellites

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide remote TV inspection capability of up to 1 mile distance from the Orbiter<br>• Provide Controls & displays in the Orbiter AFD for crew operation of the MTV<br>• Provide a color TV system with close-in zoom capability<br>• Provide MTV consumables (power & propellent) to permit >3 hr operation<br>• A non contaminating propulsion subsystem shall be provided<br>• Provide a grapple fixture on the MTV to enable deployment and retrieval by the RMS<br>• An MTV recharge/replenish station is required in the cargo bay for orbital servicing | None | • Controls & displays for MTV operation provided in the Orbiter AFD |

R81-0181-106(T)

Fig. 3.4-47 Maneuverable Television Requirements




R81-0181-107(T)

Fig. 3.4-48 Maneuverable Television Concept

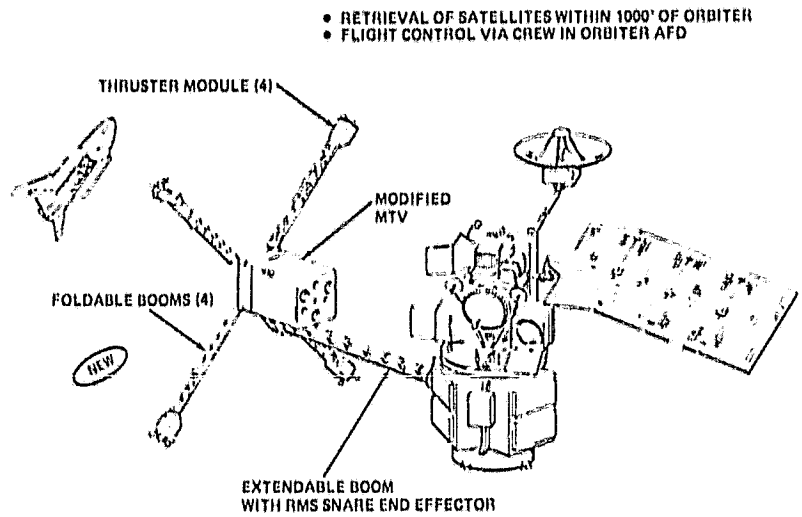
**SERVICE EQUIPMENT REQUIREMENTS: Proximity Operations Module (POM) - MTV Adaptation**

FUNCTION: Unmanned retrieval of satellites at 1000 ft separation from Orbiter

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide an unmanned vehicle, which is an extension of the MTV, to retrieve satellites weighing up to 32,000 lb<br>• Provide a cold gas propulsion system to permit rotational/translational maneuvers in any direction<br>• Locate thrusters to minimize plume impingement on the satellite<br>• Provide an RMS snare end-effector/extendable boom that extends an adequate distance to permit grappling and towing of a S/C<br>• Provide a hover/fly-around capability to enable TV inspection of the satellite prior to capture<br>• Provide TV viability to maneuver and attach the snare end-effector to the S/C's grapple fixture<br>• Provide lighting and alignment cues for the remote operator in the AFD<br>• Provide controls/displays in the AFD for crew operation of the POM<br>• Make provisions for POM stowage in the payload bay | • Provide an RMS - compatible grapple fixture mounted as close as practical to the S/C cg | • Orbiter AFD controls & displays for POM flight control/operation (crew flys POM to RMS reach)<br>• Controls & displays for snare/boom operations |

R81-0181-104(T)

Fig. 3.4-49 Requirements for Proximity Operations Module — MTV Adaptation




R81-0181-105(T)

Fig. 3.4-50 Concept for Proximity Operations Module — MTV Adaptation

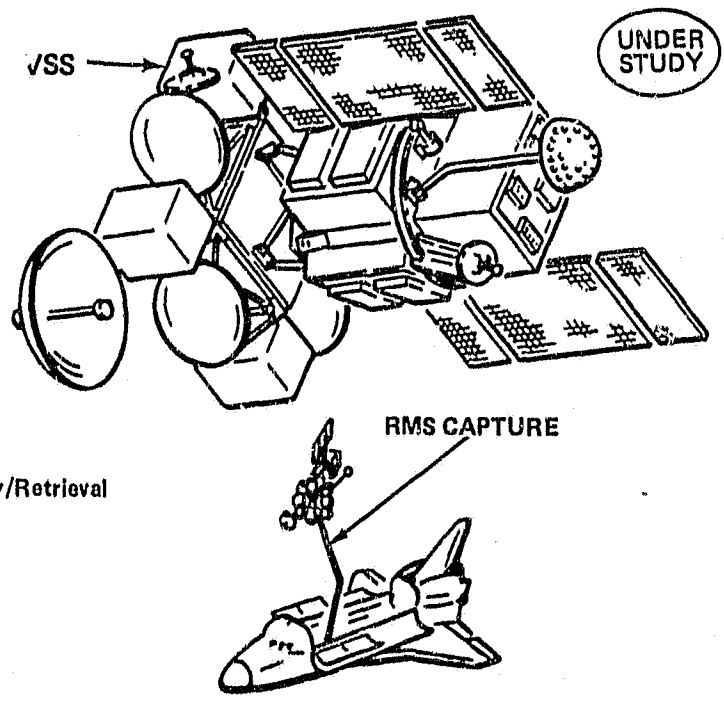
**SERVICE EQUIPMENT REQUIREMENTS: Versatile Service Stage (VSS) – Delivery/Retrieval**

FUNCTION: To transport and retrieve satellites from high energy orbits not directly accessible by the Orbiter

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • VSS designed for minimum cargo bay length<br>• Compatibility with standard HPA interface for deployment, checkout, & refueling<br>• Safing prior to Orbiter capture and stowage<br>• Provide grapple fixture for RMS deployment, retrieval & berthing<br>• Delivery or return S/C with masses about 3000 kg<br>• Rendezvous with cooperative S/C in high energy LEO orbits up to 2000 km<br>• Provide TV visibility to remotely control VSS docking to S/C<br>• Mechanism for docking & releasing spacecraft<br>• Rendezvous with Orbiter within 1000 ft<br>• Provide a clean burning propulsion system for close-in satellite retrieval and Orbiter close proximity operations<br>• Provisions for stowing the VSS in payload bay | • Compatible mechanism to interface with VSS docking mechanism<br>• Provide for satellite S&C deactivation at VSS docking | • C&D panel in AFD to support VSS:<br>– checkout<br>– remote control of docking/undocking to satellite<br>– close proximity flight control of VSS in preparation for RMS capture<br>– refueling<br>Alternate<br>• Flight control of VSS from the ground |

R81-0181-108(T)

Fig. 3.4-51 Requirements for VSS Delivery/Retrieval




R81-0181-109(T)

Fig. 3.4-52 Concept for VSS Delivery/Retrieval

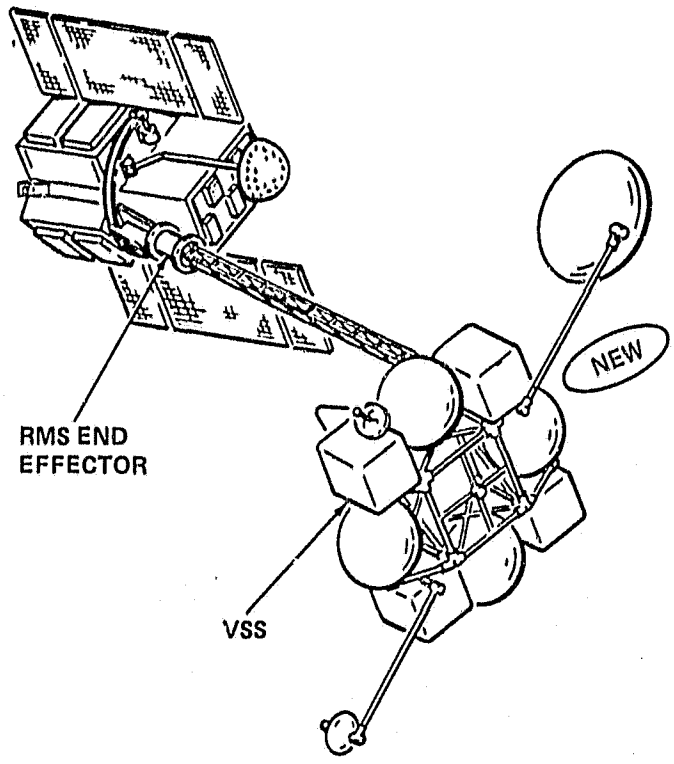
**SERVICE EQUIPMENT REQUIREMENTS: Versatile Service Stage (VSS) — End Effector Kit**

FUNCTION: To capture & stabilize an unstable satellite for docking with the VSS

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a kit with a snare end effector mounted on an extendable boom<br>• End effector kit shall interface with VSS<br>• Provide TV visibility & illumination for remote control of synchronization maneuvers and grappling operations | • Provide an RMS compatible grapple fixture, at the S/C cg, accessible to a grappler | • Maneuver/control VSS to synchronize with satellite motion<br>• Operate boom & snare end effector<br>• TV display of flight operations<br>Alternate<br>• Flight control of VSS from the ground |

R81-0181-110(T)

Fig. 3.4-53 Requirements for VSS — End Effector Kit




R81-0181-111(T)

Fig. 3.4-54 Concept for VSS With End Effector Kit

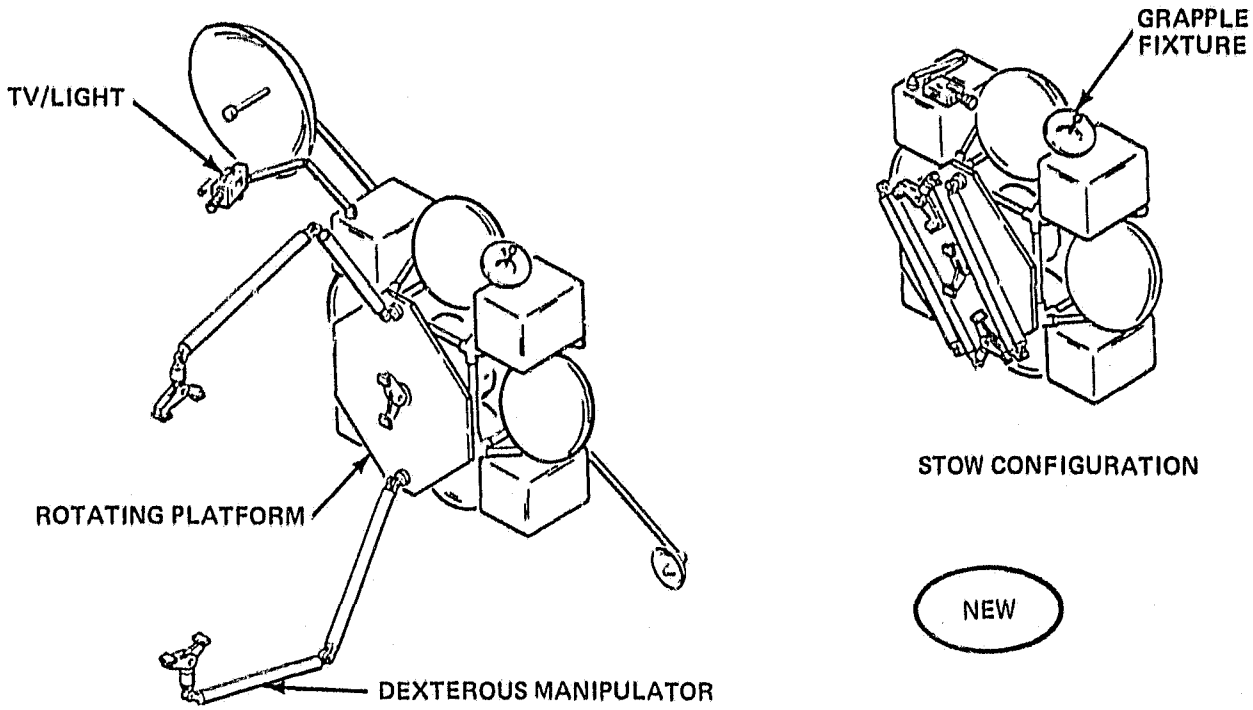
**SERVICE EQUIPMENT REQUIREMENTS: Versatile Service Stage (VSS) — Debris Capture Kit**

**FUNCTION: To capture & secure space debris to the VSS for deorbit or return to Orbiter**

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide two "crab-like" arms (dexterous manipulators) with end effectors to seize debris<br>• Provide bumper stops to enable arms to "cinch-up" debris<br>• Mount arms on a rotating base (10 RPM max) for synchronization with tumbling satellite<br>• Provide rotating base with de-spin capability relative to VSS<br>• Debris capture kit shall interface with VSS<br>• Provide TV visibility & illumination for remote control of synchronization maneuvers and capture operations | None | • Maneuver/control VSS to synchronize with satellite motion<br>• Operate manipulators to seize space debris<br>• TV display of flight operations<br>Alternate<br>• Flight control of VSS from the ground |

R81-0181-112(T)

Fig. 3.4-55 Requirements for VSS — Debris Capture Kit




R81-0181-113(T)

Fig. 3.4-56 VSS Debris Capture Concept

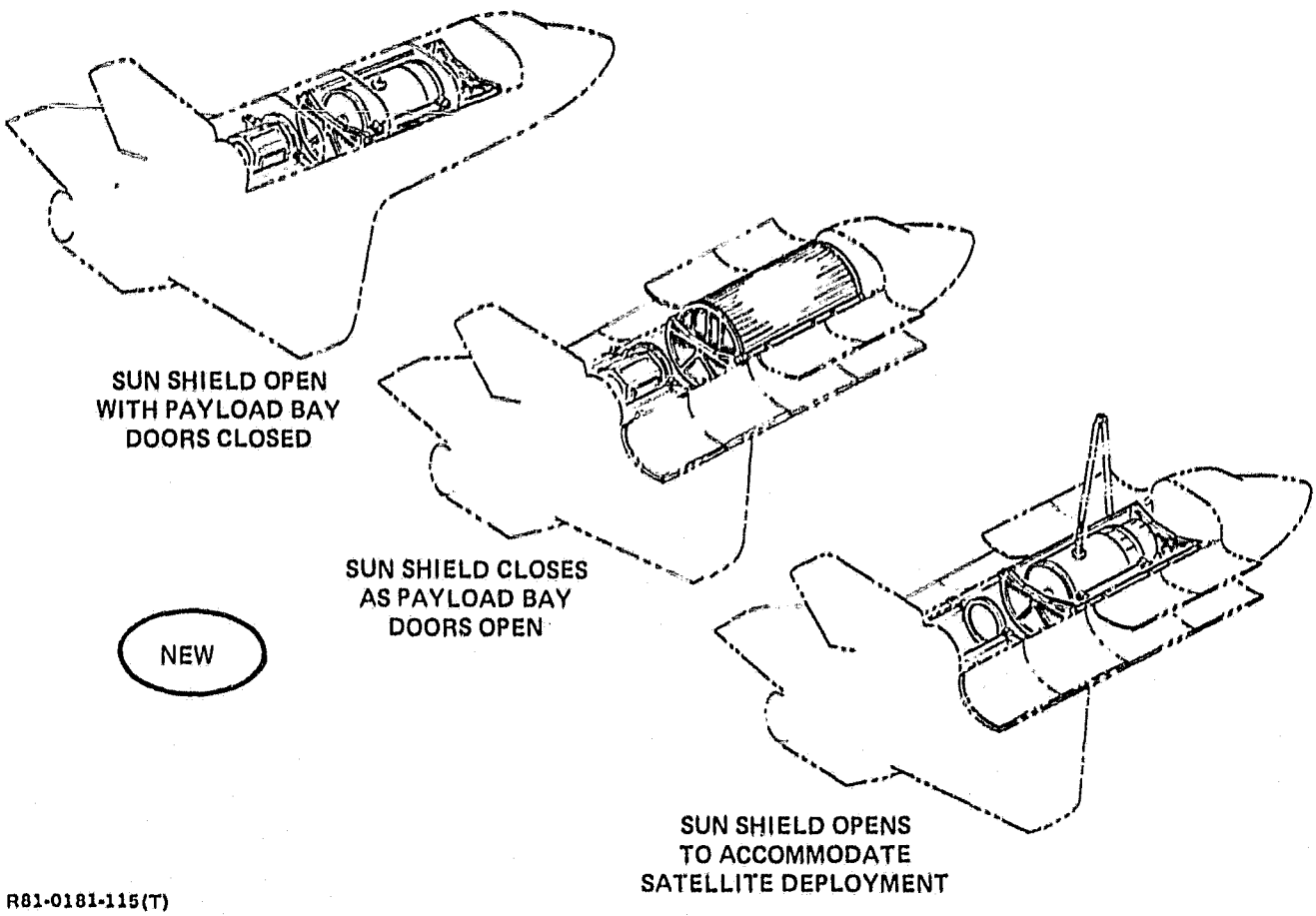
**SERVICE EQUIPMENT REQUIREMENTS: Sun Shield**

FUNCTION: To provide sun impingement protection for payloads with cargo bay doors open

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a sun shield to cover payloads in the cargo bay when the doors are open<br>• Mechanism shall be provided to activate the shield as the payload bay doors open, and to open the shield for payload deployment<br>• Shall be of modular design to provide for various length satellites<br>• Provide controls & displays to remotely operate the thermal shield from the AFD | None | • Operate thermal shield controls |

R81-0181-114(T)

Fig. 3.4-57 Sun Shield Requirements




R81-0181-115(T)

Fig. 3.4-58 Sun Shield Concept

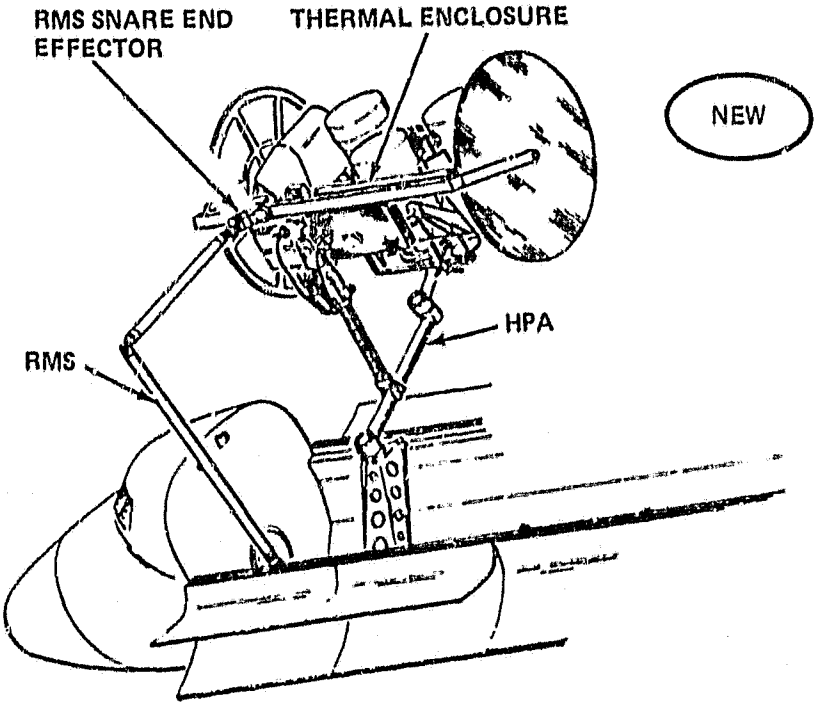
**SERVICE EQUIPMENT REQUIREMENTS: Orbital Storage**

FUNCTION: To provide a thermal enclosure for a spacecraft placed in orbital storage

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide an enclosure that completely covers the spacecraft for thermal protection<br>• Provide access to a grapple fixture for deployment & retrieval<br>• Provide for gravity gradient stabilization upon placement of satellite in orbital storage<br>• Modularize design to accomodate varying length satellites | • Provide additional grapple fixture for satellites more than 15 ft in length | • Install thermal enclosure by remote RMS operations and/or EVA support as required |

0181-070D
R81-0181-116(T)

Fig. 3.4-59 Orbital Storage Requirements




0181-089D
R81-0181-117(T)

Fig. 3.4-60 Orbital Storage Concept

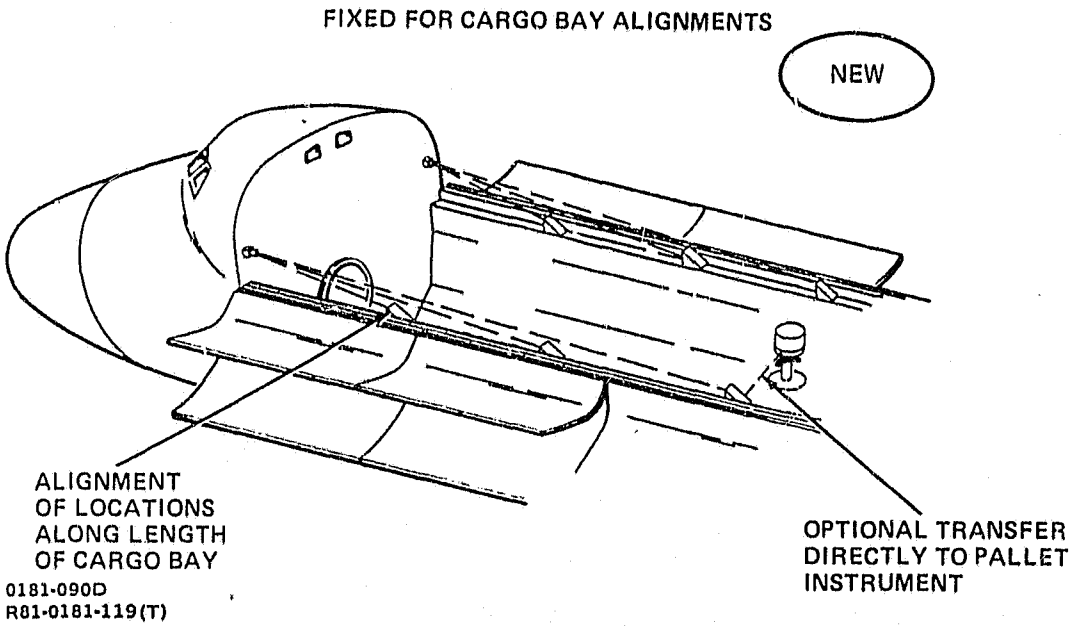
**SERVICE EQUIPMENT REQUIREMENTS: Attitude Transfer Package**

FUNCTION: To provide improved attitude/state vector information to payloads

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide means for accurately transferring attitude reference data from the Orbiter Navbase to payloads in the payload bay<br>• The goal is to improve the present misalignment error of ±2° to ±0.2° | None | • Control alignment measuring equipment deployment & transfer information to payloads |

0181-071D
R81-0181-118(T)

Fig. 3.4-61 Attitude Transfer Package Requirements




0181-090D
R81-0181-119(T)

Fig. 3.4-62 Optical Attitude Transfer System Concept

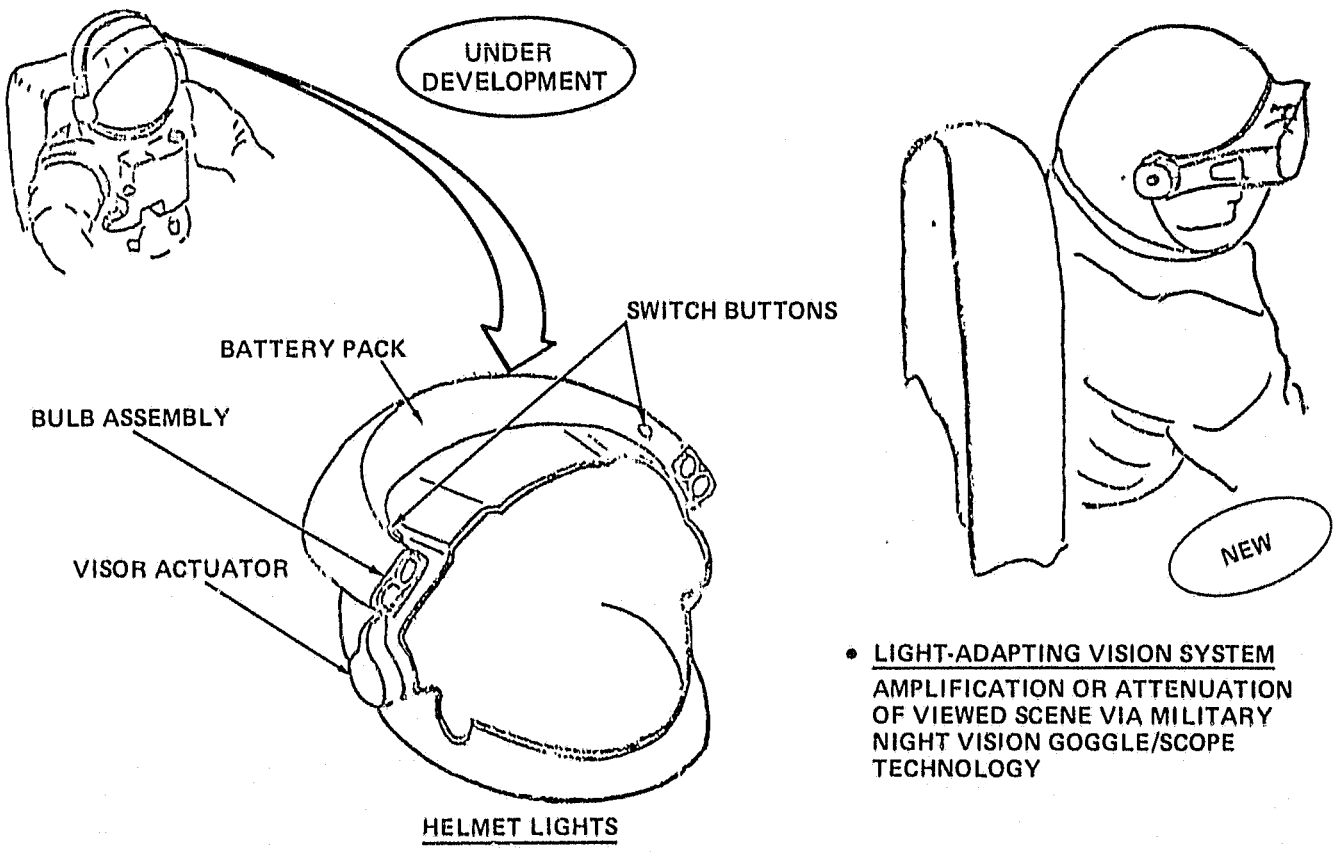
**SERVICE EQUIPMENT REQUIREMENTS: Lighting Enhancement**

FUNCTION: To enhance existing cargo bay illumination during orbital operations

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide means of enhancing illumination in the vicinity of the cargo bay<br>• Additional lighting is required in & above the cargo bay for EVA operations during dark side orbital passes | None | • Helmet-mounted light augmentation |

0181-072D
R81-0181-120(T)

Fig. 3.4-63 Lighting Enhancement Requirements




0181-091D
R81-0181-121(T)

Fig. 3.4-64 Concepts for Lighting Enhancement for EVA Operations

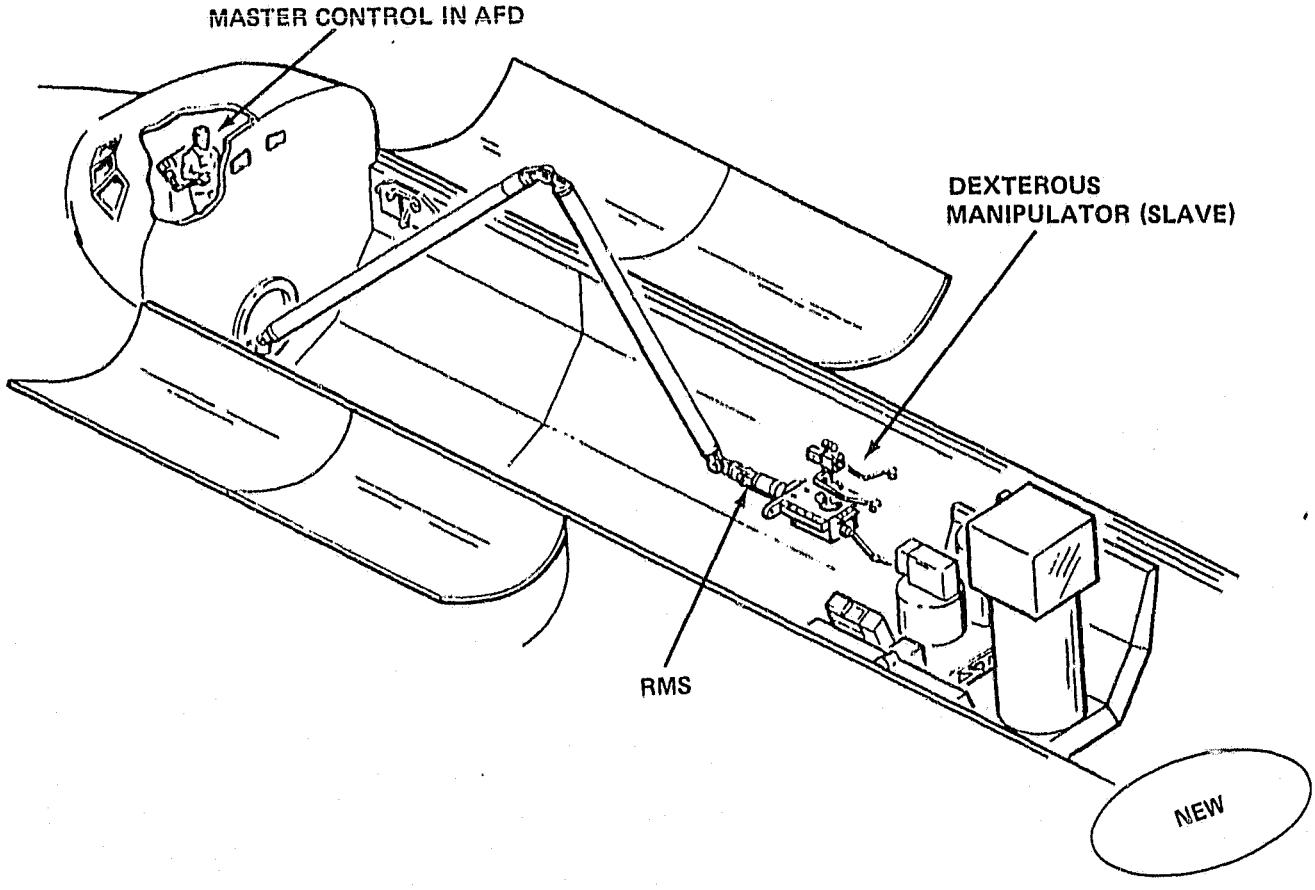
**SERVICE EQUIPMENT REQUIREMENTS: Dexterous Manipulator — RMS Adaptation**

FUNCTION: To provide capability for remote servicing operations with the RMS

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a general purpose end effector for the RMS<br>• The end effector shall have two dexterous manipulator arms and provide force feedback<br>• Provide stereo TV, lighting, payload stowage provisions, and mechanical stabilization<br>• Provide master controllers & TV displays for AFD operation of the manipulators<br>• Provide dexterity to operate equipment release mechanisms & remove/replace equipment | • Spacecraft equipment requiring removal & replacement shall be designed for easy access & fastening compatible with dexterous manipulator end effectors<br>• Equipment access & fastenings shall also be EVA compatible for backup operations | • Master controller operation & TV displays |

R81-0181-122(T)

Fig. 3.4-65 Requirements for Dexterous Manipulator - RMS Adaptation




R81-0181-123(T)

Fig. 3.4-66 Concept for Dexterous Manipulator — RMS Adaptation

**SERVICE EQUIPMENT REQUIREMENTS: Dexterous Manipulator — HPA Adaptation**

FUNCTION: To provide capability for remote servicing operations with the RMS

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a general purpose end effector compatible with the HPA work platform<br>• The end effector shall have two dexterous manipulator arms with the capability of duplicating human arms and provide force feedback<br>• Provide stereo TV, lighting, payload stowage provisions, and mechanical stabilization<br>• Provide master controller & TV displays for AFD operation of the manipulators<br>• Provide dexterity to operate equipment release mechanisms & remove/replace equipment | • Spacecraft equipment requiring removal & replacement shall be designed for easy access & fastening compatible with dexterous manipulator end effectors<br>• Equipment access & fastenings shall also be EVA compatible for backup operations | • Master controller operation & TV displays |

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Fig. 3.4-67 Requirements for Dexterous Manipulator - HPA Adaptation

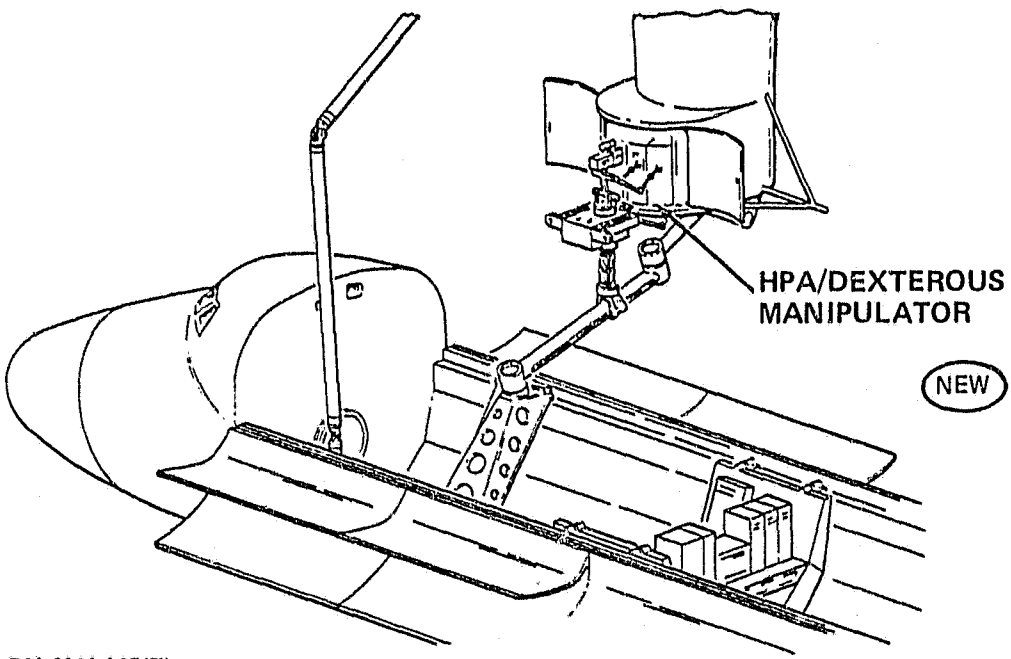


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Fig. 3.4-68 Concept for Dexterous Manipulator — HPA Adaptation

**SERVICE EQUIPMENT REQUIREMENTS:** MMS Module Handling Tool

FUNCTION: To facilitate EVA crew handling of MMS subsystem modules

| SUPPORT EQUIPMENT | SPACECRAFT INTERFACES | CREW INTERFACES |
|---|---|---|
| • Provide a manually operated actuator to interface with the MMS module attachment screws<br>• Provide tool interface with the OCP payload handling device<br>• Provide hand grips for EVA handling of tool | • Standard attachment screws | • Operate the tool during EVA replacement of modules |

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**Fig. 3.4-69 Requirements for MMS Handling Tool**

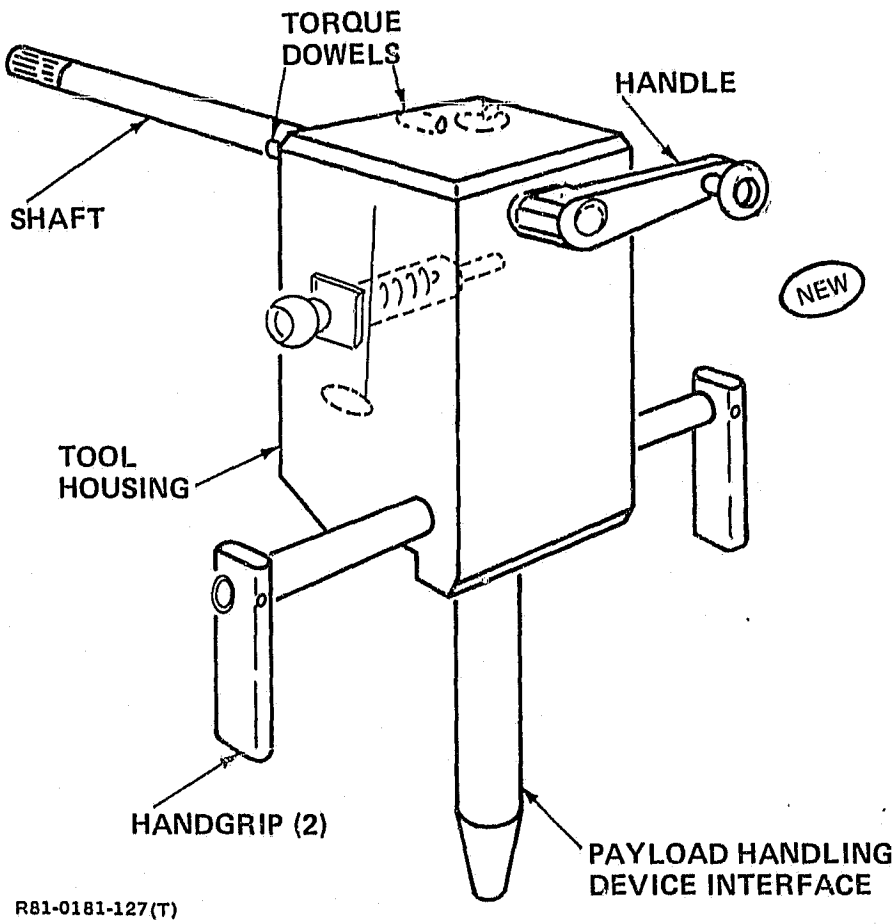


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**Fig. 3.4-70 Concept for MMS Module Handling Tool**

## 3.5 SERVICE REQUIREMENTS/EQUIPMENT SUMMARY

### 3.5.1 Service Equipment Status

A summary of the status of the service equipment identified within the 180 on-orbit operations scenarios (initial launch, revisit, and earth return) that were considered in the study is shown in Figure 3.5-1. A total of 27 items of service equipment could satisfy all of the equipment needs of the scenarios considered. Of the twenty-seven equipments identified, their status is as follows:

| | |
|---|---|
| Existing | 6 |
| Under Development or Study | 5 |
| Modifications | 3 |
| New | 12* |
| Unique | 1 |
| Total | 27 |

*Four of the 12 are optional.

For the equipment identified in Figure 3.5-1, those with connecting lines refer to equipment needs which could be satisfied by single units of service hardware adapted with appropriate kits to perform the needed service functions.

### 3.5.2 Crew Interaction

Orbiter crew interactions involve remote control functions from the aft flight deck and performance/control of service operations during EVA.

Aft flight deck crew involvements are:

- Control of Service Equipment Operations as those associated with the RMS, HPA, FSS Tilt Table, and Retention Structure Latches
- Close Proximity Flight Control of the MTV, Proximity Operations Module-MTV Adaptation, and Versatile Service Stage
- Satellite Activation and Checkout which could involve providing power to the satellite, transferring attitude and state vector information, and a minimal (TBD...standardized) checkout of status/health prior to deployment.

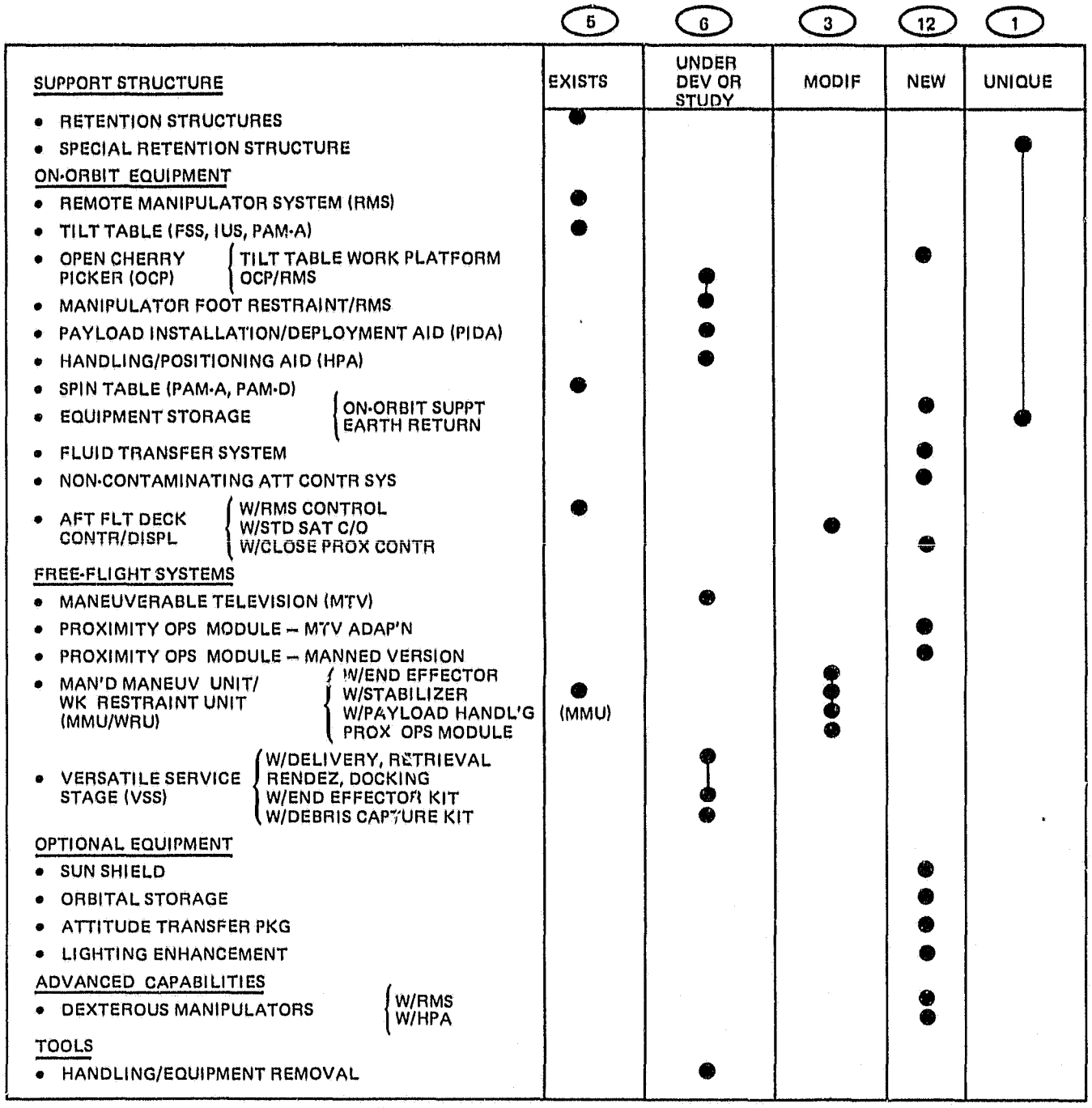


**Fig. 3.5-1 Service Equipment – Status**

Crew Extra-vehicular activities involve:

- Control of Service Equipment Operations within the payload bay, as those associated with the operation of the OCP/RMS, OCP work stations on the FSS Tilt Table and HPA, and support of RMS equipment removal and stowage operations
- Free-flight Operations Involving Close Proximity Satellite Retrieval as those associated with retrieval operations using the Proximity Operations Module - MMU/WRU adaptation
- Hands-on Repair/Maintenance including module exchange and potential fluids replenishment
- Contingency Situations with the RMS inoperative or involving mechanism hangups which would call for deployment of the MFR/RMS or appropriate MMU/WRU adaptations.

The above crew interactions clearly indicate that on-orbit crew involvement is an inherent part of satellite services in primary and contingency service operations.

### 3.5.3 Satellite Features Facilitating Servicing

Suggested satellite features that will enhance serviceability of satellites by the Orbiter/Orbiter crew are:

- A standardized interface should be established between all satellites and the orbiter to contain berthing, umbilical, and fluid transfer connections compatible with the HPA and FSS Cradle A' Tilt Table
- The extent of Orbiter crew involvement in satellite checkout operations should be standardized and, to the extent possible, minimized to reduce control/display implications on the Orbiter
- Satellite appendages should be deployable while attached to the Orbiter to take advantage of the crew's presence for backup; appendages should also be retractable to allow for servicing flexibility, access to equipment, and storage for earth return
- An RMS grapple fixture(s) should be located on the satellite to be compatible with planned servicing operations
- Satellite safing should be incorporated in all satellites calling for retrieval for servicing or subsequent earth return (e.g. expell residual propellants prior to retrieval).

Satellites intended for on-orbit maintenance should be designed with basically the same type of ground rules applied to man-tended systems, with particular attention to man-tended EVA compatibility. Five basic ground rules applying to satellites designed for on-orbit servicing are:

- Accessibility
  - EVA Servicing - Reach/Visibility Requirements
  - Mobil Foot Restraint/OCP Positioning Capabilities
- Size/Form Factors Compatible with EVA Handling
- Removal and Replacement Simplicity
  - Minimize Equipment Mounting Points
  - Mechanical Retention Mechanisms
  - Umbilical Connectors
  - Visual Verification of Connection Acceptability
- Transportability Via EVA and/or RMS
- Standardized On-Orbit Tool Usage

### 3.5.4 Observations

Overall observations that apply to service requirements and equipment identifications are summarized in Figure 3.5.2. Of major significance is that Grumman has based its identification of service equipment needs, and thus their concept definition, upon a broad base of on-orbit service operations scenarios. These scenarios have addressed operations associated with various types of satellite classes expected to be flown by the Space Transportation System in the next two decades.

- SERVICE EQUIPMENT NEEDS BASED ON ON-ORBIT OPERATIONS/USAGE
- MMU/WRU ADAPTATIONS COVER RMS INOPERATIVE SITUATIONS
- HPA VS TILT TABLE USAGE
  - WITH TILT TABLE, . . RMS LOCATES P/L ABOVE AFD FOR APPENDAGE DEPLOYMENT
    . . . RMS SHOULD "TOSS" P/L TO EFFECT SEPARATION
  - WITH HPA . . . APPENDAGES DEPLOYED WHILE HPA ATTACHED
    . . . HPA IMPARTS SEPARATION ΔV
- TYPICAL EQUIPMENT USAGE FOR DIRECT DELIVERY SATELLITE CLASS

| INITIAL LAUNCH | REVISIT | EARTH RETURN |
|---|---|---|
| RETENTION STR | EQUIP STOWAGE | RETENTION STR |
| RMS | FLUID TRANS | RMS |
| MFR | RMS | MFR/RMS |
| HPA | OCP | HPA |
| AFD C/D | HPA | MTV |
| | MTV | AFD C/D |
| | AFD C/D | |

- CLOSE PROXIMITY RETRIEVAL OF SATELLITES AT 1000 FT SEPARATION CALLS FOR PROX OPS MODULE VARIATIONS

**Fig. 3.5-2 Observations**